Holocene sea level changes in Kelang and Kuantan, Peninsular Malaysia

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by

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And the two seas (the two kinds of water in the earth) are not alike: this, fresh, sweet, and pleasant to drink, and that (other) bitter, salt. And from them both you eat fresh tender meat and derive the ornaments that you wear. And you see the ships cleaving them with its prow that you may seek of His bounty, and that you may give thanks.

(Al-Qur'an 35:12)

Declaration

This thesis is the result of my own work. Data from other authors, which are referred to in the thesis are acknowledged at the appropriate point in the text.

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Abstract

A proper methodological approach of investigating Holocene sea level changes is a prerequisite in order that the sea-level index points can be useful and significant. This requires the correct identification of the indicative meaning. The indicative meaning of the sea level indicator is defined as the altitudinal relationship of the local environment in which it accumulated to the contemporaneous reference tide level. This study identifies the index points using the litho-, bio-, and chrono-stratigraphic approach. The sea level indicator is derived from the regressive contact of the intercalated peat and marine clastic sequence, while the indicative meaning is estimated based upon the relationship with the contemporary samples.

The study was carried out at two contrasting coastal locations, the fossil sites from Meru and Mardi in Kelang in the west and Penur (north and south transects) in Kuantan in the east, while the contemporary sites are from various ecological environments from both areas. Microfossil analysis of pollen and diatoms indicates that the former are more applicable, and defined the changing microfossil assemblages within the regressive contact of the sea level indicator samples.

Seven sea level index points are identified. The finding agrees to the general assumptions of high mid-Holocene sea level history in peninsular Malaysia. A relative sea level difference between the west and east coast is indicated, but the significance, if any, is dealt with caution. The explanations of presumed differential crustal movement or sheer age/altitude variability of the index points are suggested.

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CHAPTER 1

INTRODUCTION

1.1 Preface

The evolution of the coastal plain of peninsular Malaysia has been ascribed mainly to Holocene sea level changes. Understanding how Holocene sea level behaved and its subsequent effects on the development of coastal landforms constitute the basis for understanding possible effects of future sea level changes and is a prerequisite in addressing the management of the coastal areas.

Despite studies carried out on the coastal deposit of the peninsula, the explanation of Holocene sea level changes are not well established. The present study attempts to examine the sedimentary record of Holocene sea level changes from sites in the west and east coast of the peninsula, in the Kelang and Kuantan areas. The investigation requires the identification and determination of sea level index points. Systematic study of the Holocene sediments and contemporary coastal environments using litho-, bio- and chrono- stratigraphical techniques are conducted. The interpretation of the indicative meaning and indicative range of the dated samples are very much emphasised. The indicative meaning of the sea level indicator, or its altitudinal relationship to the contemporaneous reference tide level, is determined by comparing the fossil with the contemporary assemblages, assuming the fossil and present conditions are similar. Records of relative sea level change from this investigation will be used to assess the suitability of further research in the peninsula, as well as the broader region. This will enable better understanding of the relative sea level history between local areas and in relation to a regional context and allow examination of any Holocene differential crustal movement.

1.2 Background

The Quaternary records major environmental changes due to the fluctuating climate. Throughout the approximately 1.8 million years of geological time, various phases of glacial and interglacial periods are recognised. These respective cycles of cold and warm, each lasted for several hundreds to thousands and tens of thousands of years, producing major impacts on the global environments (Williams et al., 1998; Roberts, 1998). One of the prominent effects is the changing sea level. Even though expansion and contraction of the ice sheets is prevalent in the northern hemisphere, the outcome of the growth and decay of ice sheets affects the distribution of water volume in the ocean basins worldwide.

The association of climate change with sea level has stressed the latter's importance particularly for any projection of future sea level changes. This requires an understanding of the behaviour of past sea levels, especially its recent past. The Holocene, or the postglacial epoch, documents the latest significant sea level changes that have taken place. The changes are nonetheless complex (Smith and Dawson, 1983), with different regions known to display dissimilar sea level trends (Tooley and Shennan, 1987; Pirazzoli, 1991).

The present progress of sea level research from the Southeast Asian (SEA) region is comparatively inadequate, in comparison to northwest Europe and North America. In these areas four International Geological Correlation Programme (IGCP) projects involving various aspects of sea level and coastal changes led to considerable advances in understanding. These IGCP projects, started in 1974 and each of five years duration, were designed to encourage international research on geological problems. The first was the IGCP Project 61 on 'Sea level changes during the last deglacial hemicycle (about 15,000 years), which was followed by IGCP 200 'Late Quaternary sea level changes: measurement, correlation and future applications', IGCP 274 'Quaternary coastal evolution: case studies, models, and regional patterns' and IGCP 367 'Late Quaternary coastal records of rapid change: application to present and future conditions'. These projects led to the establishment of international working groups and contributed much to the advancement of knowledge on sea level and coastal related aspects through scientific presentations, seminal papers and publications. These are especially related to the approach, especially the methodology and techniques, and the understanding of the concepts of eustasy, isostasy, crustal deformation and crustal modelling.

In Malaysia, few sea level studies had been conducted in the peninsula and were very scarce from the eastern states of Sarawak and Sabah. Sea level investigations have never been fully coordinated and were rather on an ad hoc basis. The peninsula investigations were solely from the Strait of Malacca survey (Streif, 1979; Geyh et al., 1979) and Tjia s' studies (Tjia et al., 1977; Tjia, 1980, 1992, 1996). However in the studies the approaches of sea level data collection and analysis as identified from IGCP 61 and applied during IGCP 200 were not employed (Plaasche, 1986b; Shennan and Tooley, 1987). In addition, the interpretations are incomplete because of the erroneous determination of the sea level index points. The simplified assumption of crustal stability of the Sunda shelf further limits the areal extent for investigation. The 'stable' factor constitutes the main reason that the eastern states of Sabah and parts of Sarawak were excluded, since they lie in the tectonically active region.

In peninsular Malaysia, coastal lowland straddles the length of most of its west and east coasts. These low-lying plains, commonly less than 3 m in altitude, are rather flat, and in places are up to more than 30 km wide. Many of the major towns and cities, residential places, and agricultural and economic activities are located within these areas. The importance of the peninsula coastal areas could not be more emphasised than the impact it will receive from global climate change and rise in sea level (Bijlsma et al., 1992). The much discussed projected future sea level rise has certainly opened up eyes of not only researchers of the discipline, but administrators, politicians and citizens alike, on the importance of understanding the nature of sea level change, its prediction and impact assessment (IPCC, 1994).

1.3 Aims

The aims of the research are:

(i). To examine the Holocene sea-level changes in the west and east coast of peninsular Malaysia;

(ii). To compare the Holocene sea level history of the study sites and investigate their relationship with regard to Holocene crustal movement in peninsular Malaysia;

(iii). To investigate the mid Holocene high sea level stands in the region.

To realise the first aim, suitable sites in the west and east coast of the peninsula were selected. Various factors were considered when choosing the sites. These include availability of suitable Holocene sedimentary deposits, accessibility of the sites and availability of relevant references like tidal records and levelled benchmarks. The area around Kelang in the west and Kuantan in the east are found to be the most appropriate that also meet the necessary criteria. Compared to the west coast, the east coast coastal sediment has not been much investigated litho-, bio- and chrono- stratigraphically, which further strengthens the selection of these locations. Also, the contrast of coastal setting between the west and east coast, the former fronting the sheltered and narrow Strait of Malacca while the latter the open South China Sea, made their study even more relevant.

In the light of progress in sea level research, there is very much need for Holocene sea level data from various parts of peninsular Malaysia, in which the second and third aims intend to achieve. The methodology and approach of sea level studies are becoming more rigorous (Shennan, 1982a,b, 1986a,b; Shennan et al., 1995a, 2000; Plassche, 1986b; Pirazzoli, 1996; Horton et al., 1999; Zong and Horton, 1999). Geophysical models of postglacial sea level changes, including those of Clark et al. (1978), Peltier (1987, 1998) and others, assist in the prediction at places where there is no sea level record or as testing models when records are available. The advances in sea level research necessitates a reassessment of the earlier works of Geyh et al. (1979), Streif (1979), Tjia et al. (1977) and Tjia (1992, 1996) for the region. Comparing the relative sea level records enable the identification of crustal movement between the study sites, provided the sea level index points have been determined using similar techniques and a clearly defined research methodology. The assumed tectonically stable Sundaland in which peninsular Malaysia forms a part, would thence able to be tested. The sea level data will also contribute towards testing the contradictory mid Holocene high sea level controversy from the region (Clark et al., 1978; Geyh et al., 1979; Hong, 1992; Tjia, 1996; Peltier, 1998).

1.4 Objectives

The objectives of the research include:

(i). Examine the Holocene coastal sedimentary sequences. Identify from the stratigraphy suitable sites, which record sea level history. Determine and sample the sea level indicator sequence.

(ii). Record microfossil distributions across various contemporary coastal environments. The contemporary sites should reflect a wide range of intertidal environments so that the fossil sites have a modern analogue.

(iii). Establish fossil records from a number of sites which record sea level history. Undertake systematic micropaleontological examination and age dating of the sea level indicator samples.

(iv). Establish and evaluate sea level index points from fossil sequences. Determine the indicative meaning and indicative range of the index points related to their contemporaneous reference tide level.

(v). Construct a history of Holocene sea level change. Comprehend and relate the results to those previously reported within the region.

1.5 Structure of thesis

This thesis is presented in nine chapters. Chapter One begins by introducing the relevance, aims and objectives of studying the Holocene sea level changes in peninsular Malaysia. Chapter Two reviews the present understanding of the Quaternary of the peninsula, stressing the Holocene coastal evolution in both the west and east coasts. The history of the peninsula Holocene sea level study and its interpretation is discussed.

Chapter Three reviews the published literature and summarises the basic theory and terminology of sea level change. The techniques of Holocene sea level investigations with emphasis to present study are described. Chapter Four elaborates the approach and procedures followed in the research. Both the field and laboratory analyses undertaken are explained. Chapter Five describes the study sites. The contemporary and fossil sampling transects are detailed and illustrated, the former from six environments while the latter from four sites. The contemporary samples range from the inter-tidal to supra-tidal zone, covering the tidal flat, mangrove coast, brackish *Nypa* swamp, *Acrostichum aureum* vegetation and the coastal *Pandanus* swamp.

Chapter Six presents the microfossil analysis and results. The relationship of contemporary pollen and diatom distributions across the inter-tidal zone is discussed. The advantage of pollen analysis in this study is also noted. Chapter Seven evaluates the significance of pollen and diatom assemblages as sea level indicators. The indicative meaning and range are interpreted and the sea level index points determined. Chapter Eight depicts the sea level results in the typical age-altitude graph. The Kelang and Kuantan sea level index points are analysed and discussed with regard to the models and current understanding of the Holocene relative sea level change. Chapter Nine concludes the thesis by examining the extent in which the initial aims and objectives have been met. Recommendation is made for further work and future research in other parts of the peninsula and the region.

CHAPTER 2

QUATERNARY OF MALAYSIA AND NEIGHBOURING AREAS

2.1 Introduction

The Quaternary of Malaysia and its surroundings are reflected in the region from their sedimentary deposits, submerged Quaternary landscapes, sea level fluctuations, vegetation change in the highlands, evidence of glaciation on mountain peaks and the presumed changing seasonality. Throughout the Quaternary much of the region's land masses (termed the Sundaland) experienced many cycles of high and low sea levels resulting from the interglacial and glacial phases. During the last glacial maximum (LGM), at about 18,000 years BP, the emerged Sunda Shelf is estimated to cover approximately 1.8 million sq. km (Stattegger et al., 1997) of land area (Fig. 2.1). The LGM to some degree had induced climate change effects to the region caused by the decrease of sea area and the expanded land mass (Wang et al., 1997). The estimation of LGM low sea levels varies between places: Jongsma (1970) reported 150-165 m from intertidal deposits in northern Australia; Climap (1976) estimated the sea level lower than the present by about 85 m based on dated submerged terraces along continental margins and undated wave-cut notches on Caribbean islands; Chappell and Shackleton (1986) indicated 130 m lowering from coral reef of Houn Peninsula, New Guinea; and Yokoyama et al. (2000) estimated sea level at –130 to –135 m from inferred ice-equivalent sea level in Bonaparte Gulf, Australia.

2.2. Quaternary deposits and environmental changes

In peninsular Malaysia, the description of the Quaternary deposits has followed two main concepts. The idea prior to the 1970's, which arose from study of the sediments mainly from surface outcrops, emphasised the Quaternary sediments as "alluvium", while later knowledge acquired mostly from the subsurface and coastal investigations stressed classification to formation names. Most of the early Quaternary works have been related to the investigations and on-land explorations for placer tin deposits, which had for the major part centred in the state of Perak and

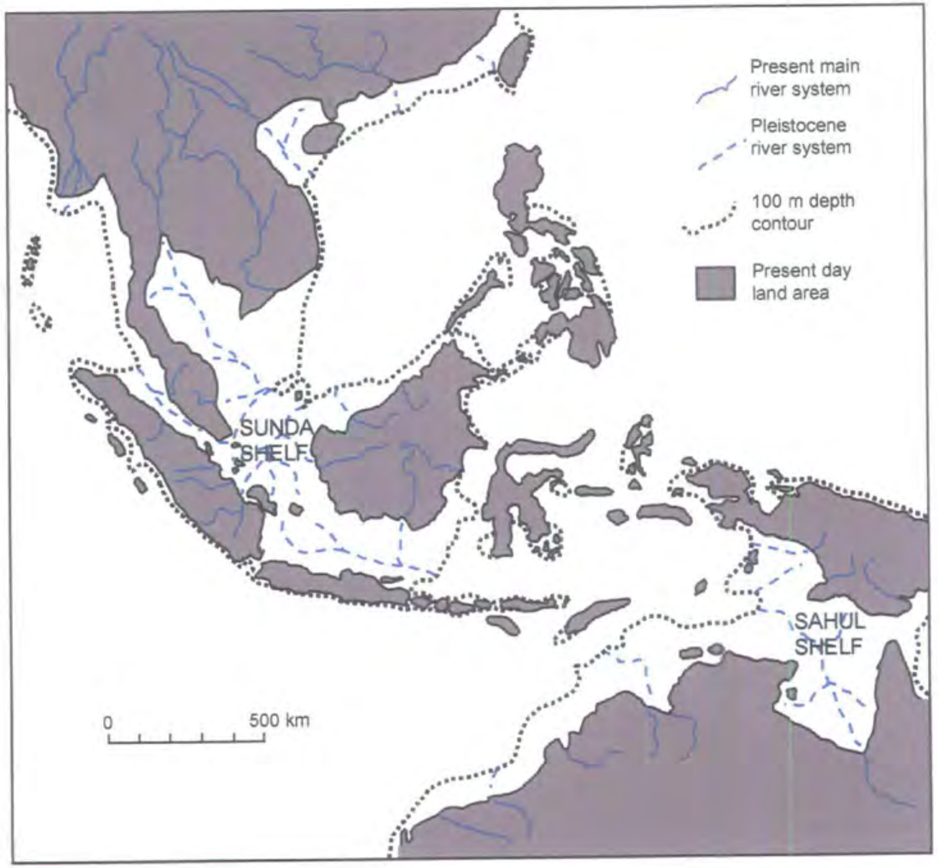


Fig. 2.1 Areal extent of exposed Sunda and Sahul shelves (black dotted lines) during the last glacial period (modified from Voris, 2000).

Selangor (states in the west coast of the peninsula), in the respective Kinta and Kelang valleys. Among many workers include Scrivenor (1924, 1949), Jones (1917), Rastall (1927), Walker (1956), Ingham and Bradford (1960), Burton (1964) and Stauffer (1973). The peninsula (also called Malay peninsula) was once one of the world's major tin ore producers, from about the early to the middle of the twentieth century.

The Quaternary deposits comprise the unconsolidated to semi consolidated gravel, sand, silt and clay mainly occupying the coastal areas, lowlands and the floors of some inland valleys. The sediments had basically been classified into Boulder Beds, Old Alluvium and the Young Alluvium, the latter two and mainly the Old Alluvium forms the bulk of the alluvial deposits. Locally the deposits also occur on terraces or as erosional remnants of higher-level deposits. The boulder beds refer to the basal deposits of very coarse gravel and always form the base of the sequence of unconsolidated sediments. The deposits, interpreted as eluvial, colluvial and water-washed boulder gravels, probably represent the initial phase of valley filling, most likely early to middle Pleistocene in age, but could be older at some places. The Old Alluvium forms a complex of unconsolidated sediments, which includes gravel, sand, silt, and clay in all possible mixtures and peaty sediments, peat and partly lignified wood and logs (Stauffer, 1973). In many places the sediments occur above the bedrock and in others above the boulder beds. The general consensus had been that the Old Alluvium is fluvial in origin, the sediments deposited in periods of rapid aggradation during the interstadials in the Pleistocene. Parts of the Old Alluvium being possibly late Tertiary are not precluded. The Young Alluvium is made up of unconsolidated deposits of sand and gravel, with some peat and clay, locally overlying the Old Alluvium and the bedrock. In the field, it is often difficult to differentiate between the Old and Young Alluvium, even though an unconformable contact has been described between the two (Stauffer, 1973). The Young Alluvium is related to the existing river systems and accumulated from the post-glacial period of sea level high stand to the present day.

Later investigations, mainly from subsurface studies of the coastal lowland areas at Taiping and Beruas, both in Perak state, differentiated four Quaternary geological formations; the Simpang, Kempadang, Gula and Beruas (Suntharalingam and Teoh, 1985; Suntharalingam, 1987). The Simpang Formation, made up of sand, gravel, clay, silt and peat, distributed and mixed in various proportions throughout the formation is defined as sediments deposited in terrestrial environments in the Pleistocene. It is correlated to the Old Alluvium in its extensive occurrences and lack of fossils. The Kempadang Formation, described as marine Pleistocene deposits (Bosch, 1988), was originally noted in the deep borings in the Kuantan coastal area named the Older Marine Unit by Che Ghani (1981). The Gula Formation, which represents the Holocene marine deposits of estuarine to shallow marine, mangrove and beach ridges, is further differentiated as the Gula Formation Undifferentiated, Port Weld Member and Matang Gelugur Member. The Beruas Formation refers to the Holocene terrestrial sediments of gravel, sand, silt, clay and peat, and is subdivided the Pengkalan Member.

There are many shortcomings in the early works (pre 1970's) which include: (i) failing to recognise the Quaternary marine deposits, (ii) confusion until the 1960's with regard to a high Quaternary sea level reaching 75 m above present level in the peninsula and (iii) a hypothesis of glacial origin of some 'boulder beds' (Scrivenor, 1918; Scrivenor, 1949; Walker, 1956). Meanwhile in the later descriptions (post 1970's), the strict usage of formation names assigned to a particular age and sedimentary environment of depositions also needs revision. This is especially true as more data are acquired with new stratigraphic information accumulated from the coastal and offshore areas.

In the offshore areas, Quaternary sediments are indicated from studies of the Strait of Malacca (Keller and Richards, 1967; Batchelor, 1979a, b; Emmel and Curray, 1982; Kudrass and Schluter, 1994), the offshore Indonesian tin islands, southeast Sumatra (Aleva, 1973; Aleva et al., 1973) and the South China Sea (Biswas, 1973; Stattegger et al., 1997). These studies, a combination of seismic profiling and coring, recognised that the sediments now submerged were made up of mainly continental and lesser marine deposits accumulated from the late Tertiary to recent times. Batchelor (1979a, b) introduced the terms Sundaland Regolith, Older Sedimentary Cover, Transitional Unit and Young Alluvium, which were tentatively correlated with the Older Sedimentary Cover with on-land Old Alluvium and the Boulder Beds. Batchelor (1988) conducted further paleomagnetic studies on the on-land sediments from mines in Selangor and Perak. The Transitional Unit indicated deposition during the early part of the Brunhes Normal Polarity Epoch (0-0.73 Ma) whereas the Old Alluvium and the boulder beds mainly formed during the Matuyama Reversed Epoch (0.73-2.48 Ma). Kudrass and Schluter (1994) however recognised four depositional sequences defined as Sequence I to IV. They indicated that all the sequences are separated by marked unconformities and proposed a correlation of the sedimentary sequences based on Late Pleistocene record of sea level changes of Shackleton (1987). Sequence I, assumed exclusively a terrestrial deposit, is assigned a tentative age of early Pleistocene to Tertiary. In contrast, Sequences II and III were deposited in an environment influenced by frequent shifts of the base level of erosion during long periods of low sea levels, tentatively correlated to respective marine oxygen isotope stage 6, 4 and 2. Sequence IV, consisting of soft marine mud, was deposited during the Holocene. Frequent mention of peat layers were noted in most of the offshore surveys. However these occurrences were not fully analysed, except for those investigated from the South China Sea by Biswas (1973), who recorded mangrove swamp and freshwater marsh spore-pollen assemblages, indicating sea level about 68 m below present day water depth, dated at 11, 170±150 B.P. In a coastal tin mine exposure at Pantai Remis, Perak, Kamaludin and Azmi (1997) investigated the interlayered peat, sand and clay deposits using both palynology and radiometric dating. The sediments, identified as Old Alluvium, are late Pleistocene in age (Kamaludin et al., 1993). Two late Pleistocene high sea stands were recognised occurring at about 14 m and 4 m lower than the present day mean sea level. The high stands were interpreted as tropical manifestations of the ameliorating interstadial climate during the Weichselian/Devensian/Wisconsin glaciation of the Northern Hemisphere.

In addition to the deposits discussed above, Quaternary basaltic flows have been described in Kuantan (Fitch, 1952). The compact, black to greenish black vesicular olivine basalt was K/Ar dated at 1.6±0.2 million years BP (Bignell and Snelling, 1977). In places along the river valleys in Perlis, Perak, Selangor and Pahang volcanic ash deposits are known. The rhyolitic ash was fission-track dated at 30,000 BP (Stauffer et al., 1980). Later radiometric determination using Ar/Ar dating however indicates an older age of 74,000 BP (Chesner et al., 1991; Rose and Chesner, 1990). The ash has been correlated to the Toba explosion in Sumatra, since peninsular Malaysia has no known Cenozoic sources for the rhyolitic material.

Apart from the mentioned sediments, soils and residual deposits (e.g. laterite) especially the former occurs widely in the peninsula. Deep weathering profiles, where weathered material exceeding 30 m thickness, are known (Stauffer, 1973).

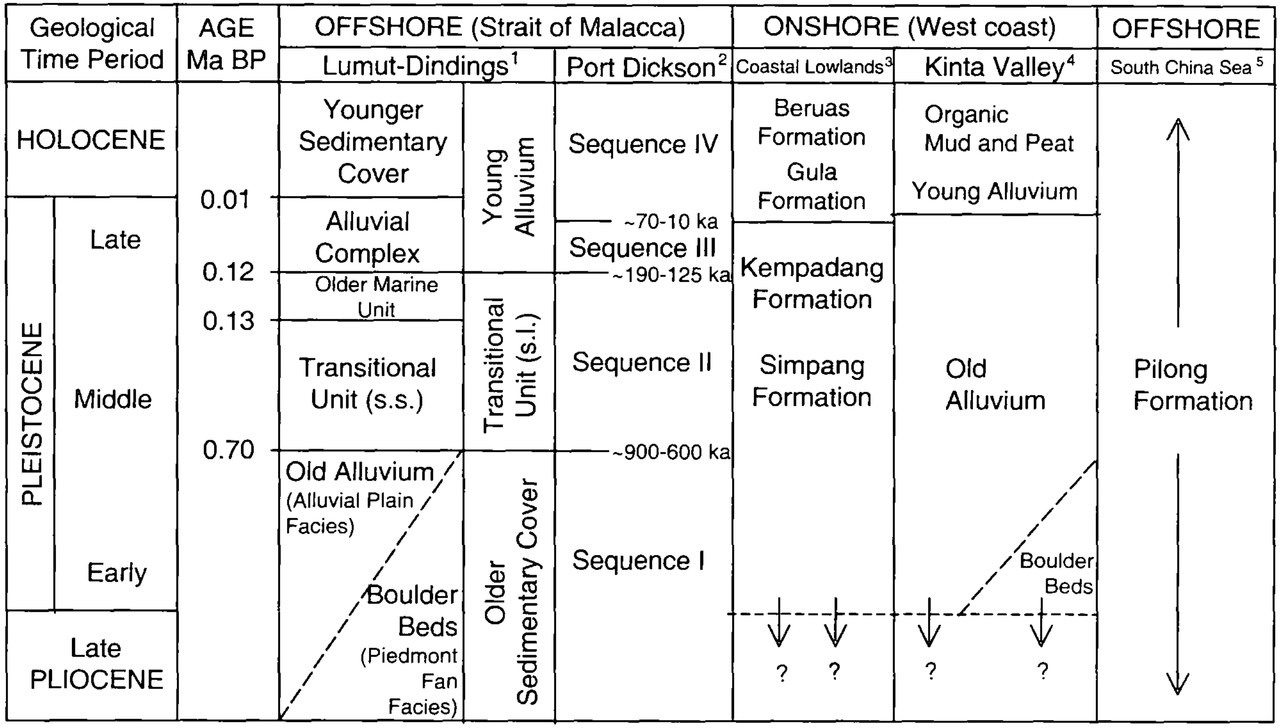
The humid tropical climate and the abundant rainfall assist the process of soil formation and weathering of the bedrock, typically the granite, which is the peninsula's main rock type and forms the hilly and mountainous central backbone.

The vegetational adaptation in response to changing climate is depicted from New Guinea (Flenley, 1979) and the Sumatra/Java Highlands (Flenley, 1985; Morley and Flenley, 1987; Stuijts et al., 1988). A respective depressed forest limit from 1000-1900 m and lowering of altitudinal zone boundaries of the lower montane forest from 400-800 m during the last glacial maximum are indicated. Seasonal climate during the middle Pleistocene has been inferred for peninsular Malaysia from the finding of a *Pinus* dominated sample from Subang near Kuala Lumpur (Morley and Flenley, 1987). *Pinus* is presently not native to peninsular Malaysia but is widespread in Thailand and the Philippines. Characteristic lower rainfall and a longer dry season during the glacials has been suggested for Southeast Asia (Verstappen, 1980). Koopmans and Stauffer (1967) discussed evidence of at least once glaciation on the summit of Mount Kinabalu (4100m, the highest mountain in southeast Asia), northwest Sabah, during the Pleistocene. They described large and small-scale physical features, such as polished rock surfaces, concentric cracks and gouges and rectilinear glacial grooves, as the results of glaciation of the summit and upper flanks of Mount Kinabalu to about 3050 m. Flenley and Morley (1978) indicated a minimum age of 9186±120 BP for the deglaciation of Mt. Kinabalu.

Figure 2.2 summarise the Quaternary correlation chart for the peninsula. The chart is based on both the onshore and offshore stratigraphic data. It is obvious from the chart that the stratigraphy is mainly derived from the west coasts studies. The onshore sources are compiled from Walker (1956), Stauffer (1973), Suntharalingam (1983), Suntharalingam and Teoh (1985) and Kamaludin et al. (1993), while the offshore from Batchelor (1979b, 1988), Kudrass and Schluter (1994) and Du Bois (1985).

2.3 Holocene evolution of Peninsular Malaysia

The Holocene evolution in the region was very much influenced by sea level change since the LGM. Almost uninterrupted rise in sea level to around 6,000 years ago (Fairbanks, 1989; Chappel and Polach, 1991) had dramatically altered the geography of the Sundaland and its coastal sedimentation pattern, while subsequent



Source:
1. Batchelor (1988)
2. Kudrass and Schluter (1994)
3. Suntharalingam (1983)
4. Walker (1956), Stauffer (1973)
5. Armitage & Viotti (1977)

Fig. 2.2 Quaternary correlation-chart for Peninsular Malaysia lowering of the sea to its present position (Geyh et al., 1979; Tjia, 1996) had produced a consequent lateral shift of the coastline. The Holocene deposits of peninsular Malaysia are thus confined mainly to its coastal areas, which had largely evolved after the mid-Holocene high stand of sea level (Hillen, 1986; Bosch, 1988; Kamaludin, 1989 & 1993).

The coastal lowlands form a generally low relief plains less than 3-5 m in elevation and vary in width from zero, where bedrock hills form the actual coast, to 20 km or more along fairly large stretches. They are widest in the deltaic areas and may extend to 60 km wide around the mouth of Perak River. The plains show a wedge feature where sediments thin inland but thicken seaward as indicated from the geophysical survey of the Selangor coastal plain (Hagen and Streif, 1976 in Bosch, 1988). The thickness of the Quaternary coastal deposits in major river deltas may exceed 100 m. Seismic survey of the Kuantan coastal plain did not detect bedrock at 150 m depth (Ho, 1984). In contrast the thickness of the Holocene sediments is generally less than 15 m but may vary between places. Soft marine clays 20-40 m thick described in Port Kelang was ascribed as Holocene (Mahillah, 1971 in Bosch, 1988), but at Pantai Remis, Perak, marine deposits less than 3 m thick is underlained by sediments dated 28900±3000 BP (Kamaludin et al., 1993).

The Holocene coastal deposits of the peninsula constitute mainly the marine clays, sandy beach ridges and woody peat. In the inland and hill areas, limited Holocene deposits are found. When present they commonly form the surface cover (less than few metres) of the river valleys. The marine clay is greenish grey, very uniform in texture, has a strong acid sulphate smell, often contains significant amount of silt, minor amounts of fine sand and rare shell remains, deposited in mangrove/tidal flat/estuarine environments. Palynologically, mangrove pollen assemblages in the clay generally constitute more than 50% of the total pollen content (Hillen, 1986; Kamaludin, 1989). The marine clay has been the subject of geotechnical investigations due to its rather thick and widespread occurrence throughout the region and its importance for coastal engineering. Kobayashi et al. (1990) indicated that the coastal clays found in Malaysia, Singapore and Indonesia could be differentiated into two units, the upper and lower marine clay layer, based on the preconsolidation pressure where the over-consolidation ratio is greater for the lower than the upper marine clay. They also noted an intermediate stiff clay layer 2 to 5 m thick sandwiched between the upper and lower layers at about 15 m below

MSL. Che Ghani (1981) pointed to the presence of about 1 m of mottled clay interpreted as continental deposits at about 20 m MSL sandwiched between marine clays, from a deep borehole transect at Kuantan in the peninsula east coast. Kamaludin (1989) noted occurrences of a stiff clay layer underlying the marine clay sequence in places along the west coast. The stiff clay is commonly mottled and devoid of palynomorphs, and is explained as formed by sub-aerial exposure due to lowering of sea level. Geyh et al., (1979) radiocarbon dated three wood samples from a thick sequence of mangrove deposits which gave respective dates of 7175±70, 7440±175 and 7560±135 BP from depths of -5.00 to -5.10, -5.80 to -5.85 and -7.50 to -7.55 m MSL, from the Strait of Malacca survey. The dates of Geyh et al. (1979) give an indication that the upper marine clay layer of Kobayashi et al. (1990) is at least Holocene in age while the lower clay layer is most probably Pleistocene.

In inland areas of the landward coastal plain, peat swamps are fairly common. Studies of the peat indicate that the coastal freshwater peat of the west coast had commonly developed on clays of marine/brackish swamp settings (Haseldonckx, 1977; Hillen, 1986), while in many parts of the east coast it has developed on sands. The peat swamps of the peninsula are relatively shallow and rarely exceed 6 m (Anizan, 1992). The radiocarbon ages of the basal coastal peat layers from the west coasts show a range from 2.1-7.2 ka BP, with most dates within 4-5.5 ka BP (Coleman et al., 1970; Haseldonckx, 1977; Geyh et al., 1979; Bosch, 1988).

The coastal lowlands of the peninsula also include areas of riverine alluvial plains occurring inland of the low relief coastal plains. The plains are slightly higher in elevation generally at least more than 2 m MSL, mainly represented in Perak in the west coasts and Kelantan in the east but are also found inland along most of the major rivers (Bosch 1986a, 1986b, 1988). The plains generally form the intermediate zone between the coastal plains and the high lands, the hills and mountains. The alluvial plain deposits constitute clay, silt, sand and gravel of mainly fluvial origin. Often differentiation between Holocene and the older deposits is difficult when there are no clear changes in lithology. In cases along the west coast the sediments could be found overlying Holocene marine clay. Bosch (1986b) indicates a mangrove peat dated 7100±120 years BP underlying fluvial plain sediments at Kampong Tasik Pauh, Kelantan.

2.3.1 West coast

The coastal physiography of the west and east coasts is rather different. The west coast being sheltered and shielded from the Indian Ocean by Sumatra, has the major part of its shoreline swamped by mangrove vegetation. The coastal sediments are commonly made up of marine clay. Presently sedimentation of marine clay is still continuing along the coasts. Between 1914 and 1969, even though both accretion and retreat of the mangrove shores are noted at Kuala Kurau (northwest of peninsula), horizontal accretion rate of 18 to 54 m/year was indicated at certain parts of the coasts (Kamaludin, 1993). In most Holocene coastal transects marine clay forms the underlying sediment often overlain by peat and/or beach ridge deposits.

Sandy beaches in the west coast are few. When present they are quite short (a few hundreds of metres), except for the shoreline of Prai (north-east of the peninsula) which is continuous for nearly 14 km. A series of inland sandy beach ridges (locally known as permatang) occurs at a few scattered places. In Prai the most inland sand ridge near Kepala Batas, about 6 km from the coast, overlies a thin peat layer dated at 6472±120 BP (Kamaludin, 1990). In Beruas, Perak the paleo beach ridge (also referred as a beach barrier) shows a wedge shaped feature trending about 18 km in length and up to 4 km wide, with the inland most edge at Kampong Padang Serai 8 km from the present coast (Suntharalingam, 1987). These paleoridges in both Prai and Beruas (about 100 km south of Prai) show orientations generally parallel to the present coastline. Also, the respective beach crests and base levels of these most inland ridges show quite similar elevations, in Prai 5 m MSL and base at 2.1 m MSL while in Beruas 5.5 m MSL and base 2.5 m MSL, the sand ridge being about 3 m thick in both places. At Lekir, Perak a 3 m thick layer of chenier sands was dated 5220±110 (Bosch, 1986a). At Pantai Remis, Selangor, shells and small amount of sands made up the present short beach stretch. Short and rather long (few km) stretches of relict chenier-like shell ridges are known in few places in the west coasts. These ridges can be 3 m thick and about 90 m wide. The shell ridge located about 10 km inland overlying mangrove/tidal flat deposits near Bagan Datok, Perak was dated 340±80 BP (Bosch, 1986a), indicating the present coastline had since accreted at a rate of approx. 30 m/year.

2.3.2 East coast

The east coast is characterised by long stretches of sandy beaches facing the South China Sea. The continuous sandy shore is only interrupted by river outlets and cliffs, as in the southeast part of the peninsula. In major deltas of the Pahang and Kelantan rivers, beach ridge systems can be fairly extensive. In the latter, the beach ridges extend up to more than 11 km inland from the present coast (Koopmans, 1972). Throughout the east coast the beach ridge system forms a series of elevated parallel features, separated by depressions (swales) often filled up by silt and clay. Earlier settlement patterns follow the ridge system (permatang), since they are dry and higher than the surrounding areas. The vegetation of the sand ridge itself is quite sparse. Nossin (1965) mentioned that the sandy surface allows only savannah-like vegetation of open bushes and lallang (grasses) to thrive. For ridges fronting the sea, at many places *Casuarina* and coconuts are the most commonly observed trees, probably occurring both as wild and cultivated. Mangroves are limited, confined only to the sheltered estuaries and bays. Peat swamps are quite widespread especially south of Kuantan.

The beach ridge deposits of the east coast have been described as attaining three main levels of crest height, >15 m, 9-11 m and <9 m respectively from the most inland occurrence to the present coasts (Teh, 1992). They are denoted the older and younger series; the latter form the two lower levels of Holocene deposits. The peat at the base of the younger series at approx. 1.0 m MSL found near Selising, Kelantan was dated 4350±100 BP (Bosch, 1986b). The mode of formation of the younger series is described as offshore origin, stranded as an emerged feature due to the fall in sea level, while the older series is describes a transgressive formation driven shorewards by the rising sea (Nossin 1962, 1965; Teh, 1992). The thickness of these ridges generally varies from few metres to more than 8 m as noted in Kuala Besut.

Even though beach ridges are the prominent features of the east coast, swampy plains cover extensive areas of the lowland coastal plains. Both fresh water and brackish water swamps predominate. The swampy condition is probably mainly caused by the younger series of beach ridges, which align the present coasts, impede drainage and block the river outlets altogether. In the state of Pahang, much of the coastal plain is presently forested and with permanent swamps.

2.4 Holocene sea levels

Changes in sea level in peninsular Malaysia have been recognised for quite some time, probably as early as the 14th century as meticulously detailed by Khoo (1996) who reconstructs the geomorphology of the Merbok estuary, Kedah, from historical accounts, archaeological records and geological and geomorphological field data. The estuary had formed an important entrance to the Bujang Valley prehistoric entreport site in which traders from Arabia, India and China had converged. The site flourished from the 4-5th century until the early 14th century before it became less important and abandoned due to shallowing of the sea, or fall in sea level, exacerbated by increased sedimentation. Low (1833) noted that the Kedah coast opposite Penang island had in many parts "been rescued from the sea", implying an earlier higher sea level. In later reports and until the 1970s, 'high sea level' during the ancient times were widely mentioned and interpreted. Estimates of high sea levels like 60-90 m by Scrivenor and Jones (1919), and 16 m from coastal borehole elevations (Scrivenor, 1949) have been proposed. Fitch (1949) attributed the raised beaches in the east coast, which stand up to 11 m and 4.5 m above sea level to recent land emergence due to a fall in sea level. Walker (1956) suggested high sea level of 70 m above present for the deposition of the Quaternary Old Alluvium of peninsular Malaysia while Burton (1964) mentioned the 'Older Alluvium' of Singapore and Johore as possibly deposited in an early Pleistocene sea standing about 76 m above present level. This description of Quaternary high sea levels persisted despite the lack of convincing evidence. The controversies regarding shorelines higher than 15 m above present in the peninsula was subsequently dismissed by Haile (1971) who stressed that there is no acceptable evidence of Quaternary submergence of the peninsula, apart from a Holocene submergence of at least 6 m.

The concept of eustatic changes in sea level as discussed by Fairbridge (1961), introduced by Suess (1906, in Fairbridge, 1961), has influenced the development and perception on sea level studies worldwide. The late Quaternary sea level history of peninsular Malaysia was developed in a similar manner. The late Pleistocene-Holocene sea level changes in the Strait of Malacca was investigated by Geyh et al. (1979) and Streif (1979), while mid-Holocene to present sea level for peninsular Malaysia was generalised by Tjia et al. (1977) and Tjia (1980, 1992, 1996). The techniques of sea level studies differ between the Strait of Malacca survey and that of Tjia's investigation. Both Geyh et al. (1979) and Streif (1979) utilised depositional sea level indicators from on- and offshore data south of Strait of Malacca, from south of Kuala Lumpur to the southern tip of the peninsula, spanning about 300 km, to propose a Holocene sea level graph (Fig. 2.3). The LGM smooth sea level rise to mid-Holocene at a suggested decelerated rate of 15-6 mm/year is depicted. However in the study, biostratigraphic investigation and stratigraphic correlation of the sediments were not performed. The dated sea level indicators are from basal peats, mangroves and organic cover sequences, where 33 dates within conventional C-14 range were obtained, in which 23 are within the Holocene. Streif (1979) briefly discussed how the sea level graph is derived and what it indicates, including the indicative meaning of the dated material, the indicative range of a sample, uncertainties of height determination and the sigma interval of the ^{14}C dates. Meanwhile, Tjia (1970) approached Holocene sea level study by investigating the morphological feature of the coasts and sea floors. Examples include beaches, abrasion terraces, notches, and breaks in slope. Subsequently, Tjia et al. (1977) indicate the usefulness of shoreline biological indicators such as oysters, barnacles, molluscs and shells in sea level study and reported many dates, mainly from fossil rock-clinging oysters in growth position, sampled throughout the peninsula. The combination of dates and elevations were then used to develop the sea level graph of peninsular Malaysia. Referring to the peninsula as part of the geologically stable Sundaland, since the early Tertiary (Tjia, 1980, 1992, 1996), more than 130 radiocarbon dates throughout the peninsula were used to reconstruct the paleo sea level. By 'stable', Tjia (1996) implies comparatively only very slow vertical crustal movements at rates 2 to 3 orders lower than those determined from the mobile regions, which experience rates reaching 10 mm/year (Fig. 2.4). Tjia (1992, 1996) presented the sea level graph showing scattered data points without specific indicative trends and suggested 3 possible routes of late Holocene sea level fall, depicted as fluctuating, progressive but gradual lowering, and stepwise recession to the present day (Fig. 2.5). However, in interpreting the sea level index points the indicative meaning and indicative range (Shennan 1982a,b, 1986b; Shennan et al., 1983; Plaasche, 1986b) should be taken into consideration. Furthermore, the wide geographical coverage and large scatter of data used by Tjia should probably be tackled by site-specific plots or within the context of the local sedimentary basin.

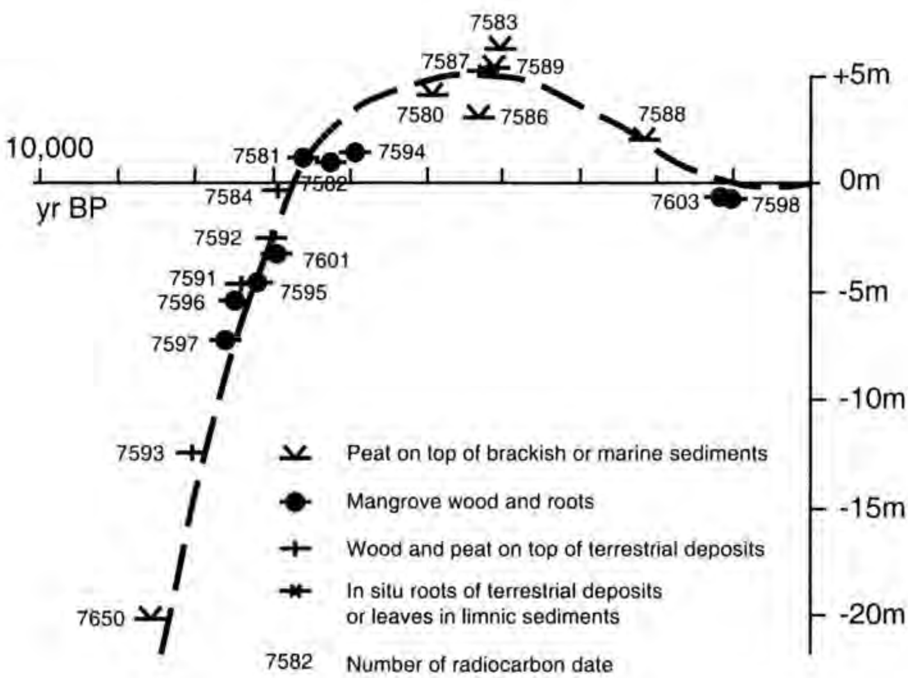


Fig. 2.3 Holocene sea level changes from the Strait of Malacca (after Geyh et al., 1979).

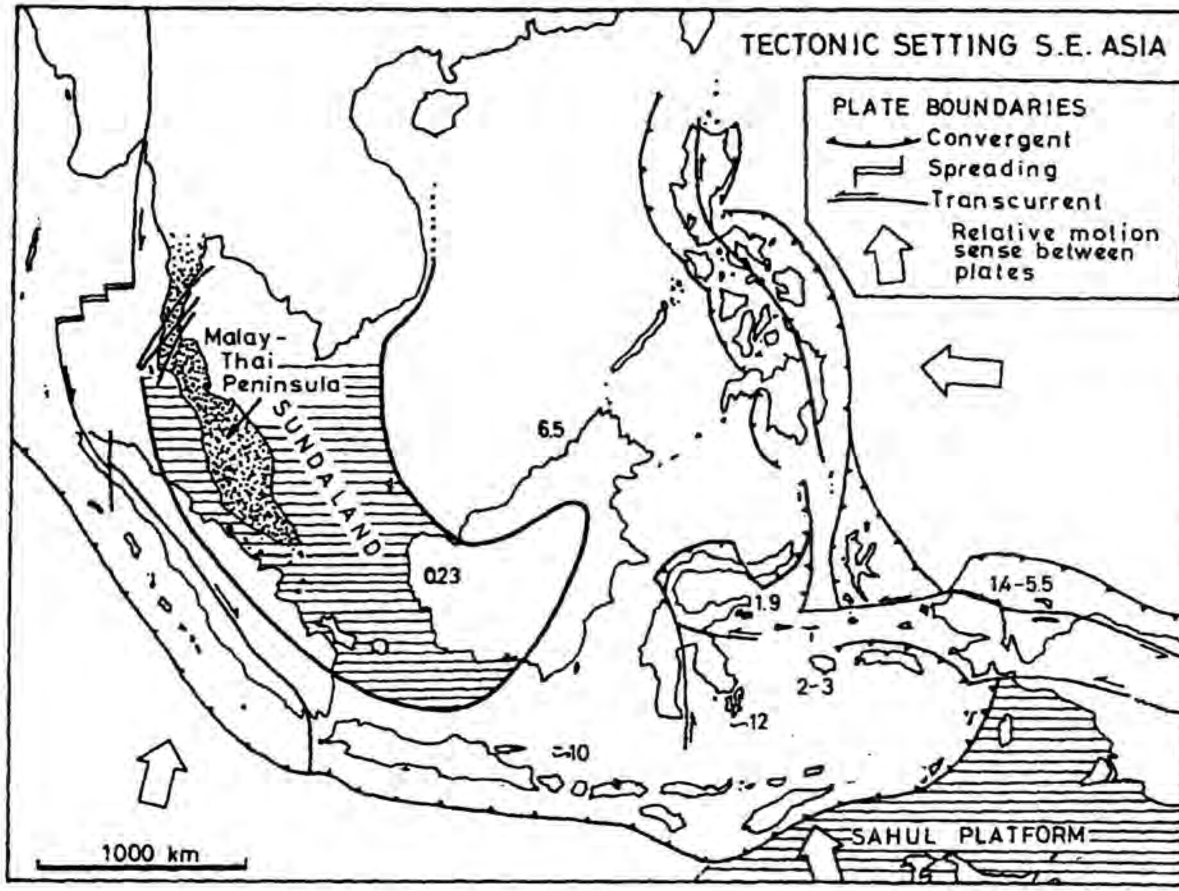
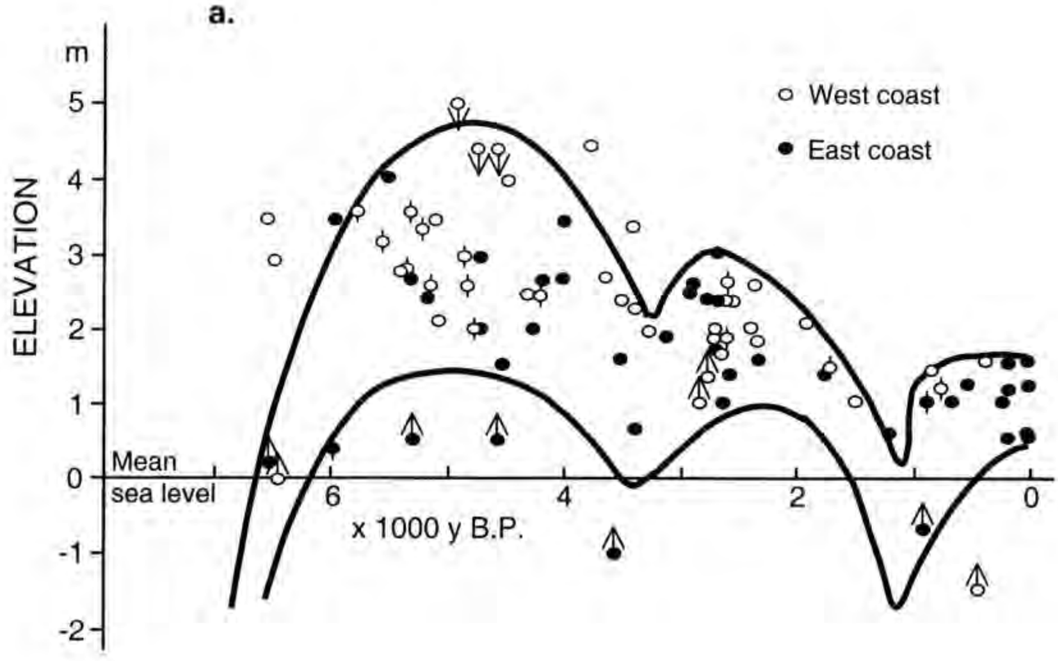


Fig. 2.4 Tectonic framework of Southeast Asia. Numbers are examples of rates of vertical movement in mm/year (from Tjia, 1996).



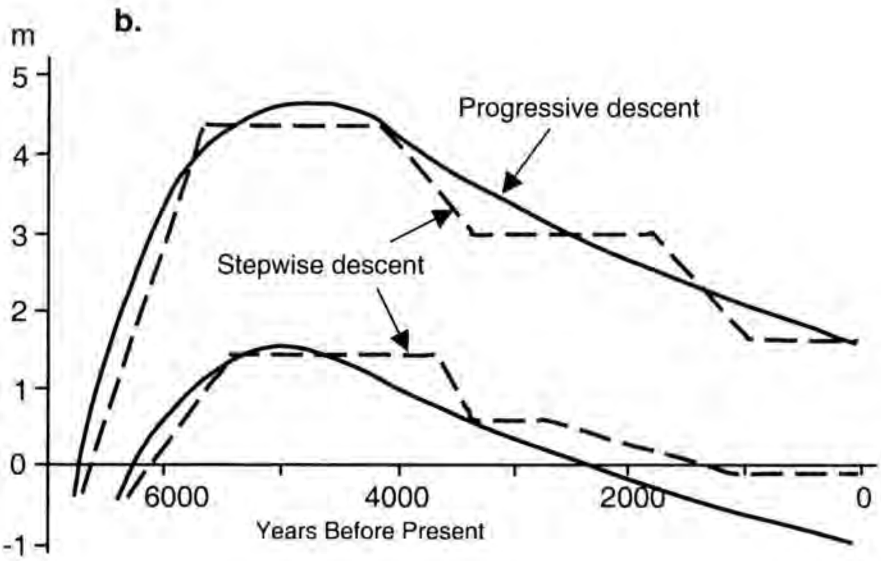


Fig. 2.5 Holocene sea level interpretation for peninsular Malaysia. (a) Fluctuating; (b) Progressive and stepwise lowering, (after Tjia, 1992 & 1996).

Pirazzoli (1996) stated that sea level changes since the LGM have varied greatly from place to place; the result has been a wide range of regional relative sea level histories.

The nature of post-glacial sea level changes have been discussed for many decades. A broad division into either Fairbridge or Shepard schools of thought was suggested (Kidson, 1982). The former indicated that the rise of the sea was spasmodic and include regressive as well as transgressive phases while the latter argued for a smooth exponential trend. The presence of the intermediate stiff grey clay layer between the marine clay units in the Holocene coastal lithostratigraphy in many parts of the region (Kamaludin, 1989, 1993; Kobayashi et al., 1990), showed an interruption of the marine sedimentation process. Even though the age of the stiff clay is not determined, the widespread occurrence points to a lapse period of the post-LGM sea level rise, regional in nature, at least in the Sunda Shelf area. The reported presence and significance of the thin organically rich layer underlying the stiff grey clay needs further investigation.

The mid-Holocene sea level of peninsular Malaysia, from both the Strait of Malacca (Streif, 1979; Geyh et al., 1979) and Tjia s' studies (Tjia et al., 1977; Tjia, 1970, 1980, 1992, 1996), indicated a sea level high of about 5 m above present level, the former between about 4-5 ka BP and the latter about 4.5-5.5 ka BP. The mid-Holocene higher than present sea level for the region is, however, not in agreement with the geophysical model of Clark et al. (1978), Clark and Lingle (1979) and the discussion of Kidson (1986). Clark et al. (1978) modelled global changes in postglacial sea level as a result of the deformation of the earth's surface and its geoid by the changing ice and water loads. They classified the region within their 'zone IV-oceanic submergence' form of relative sea level curve, predicting dominant submergence and no emerged beaches (Fig. 2.6). Hong (1992), supporting the proposed model of Clark et al. (1978), argues for the mid-Holocene eustatic high stands for the east and southeast Asian coasts. However, Peltier (1998) showed that the equatorial Pacific Ocean and its western margin (which was earlier termed the 'far-field' region or part of zone IV of Clark et al. (1978)) reached a high stand at 4-6 kyr ago. He further discussed that, in so far as the glacial isostatic adjustment (GIA) related processes that control relative sea level history in this region is concerned, the western equatorial Pacific Ocean and its margin have recently 'emerged' as the region of greatest contention. To the north and south of peninsula Malaysia, evidence of

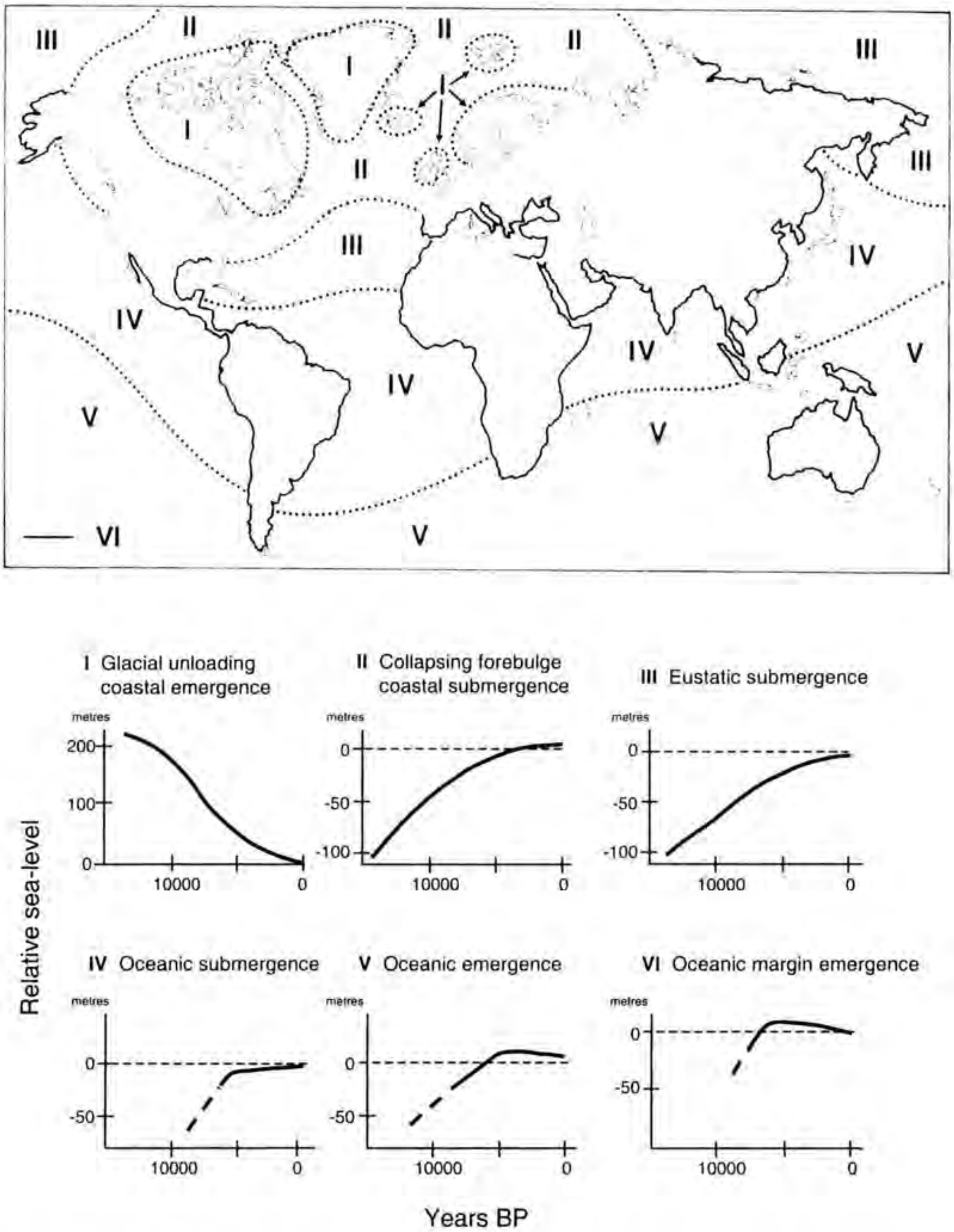


Fig. 2.6 Model of the global changes in postglacial sea level as a result of the deformation of the earth's surface and its geoid by the changing ice and water loads (after Clark et al., 1978).

high mid-Holocene sea levels indicates higher by about 4-5 m and +3 m from Thailand (Sinsakul et al., 1985) and Singapore (Hesp et al., 1998) respectively.

CHAPTER 3

SEA LEVEL ANALYSES

3.1 Introduction

The understanding of various sea-level terms is a prerequisite in sea level analyses. This chapter will describe the commonly used terms in sea-level research. Emphasis is stressed on the definitions that are relevant to the present study.

3.2 Definition of sea level

Sea level is basically defined as the height (altitude), relative to some datum, of the surface of the sea as measured at a given place and time (Plassche, 1986a). The level of the surface of the sea at a given location changes continuously throughout the tidal cycle, between the high and low water, levels which vary between 'spring' and 'neap' values depending on the position of the moon in relation to the earth. The continuous record of height of tide observed at equal intervals of time, in relation to a fixed benchmark, determines the average levels of the sea. Mean sea level (MSL) is the average level of the surface of the sea calculated from a large number of observations taken at equal intervals of time (commonly one hour) over a period of several years (Table 3.1). In theory, it is the surface level, which the oceans and seas of the world would adopt if tidal forces ceased to operate (Doodson and Warburg, 1941). Being a calculated value based on measurements of only the last 150 years, MSL could not be derived from the sedimentary deposits or landforms (Jardine, 1986). By comparison, mean tide level (MTL) at a given location is the average value of all the levels of high and low water at that location. Its former value may be determined from the sedimentary and geomorphological record of former high tide, low tide and tidal range values. Thus relative sea level curves plotted using MSL in effect represent MTL. In peninsular Malaysia MSL is referred to the Port Kelang Tide gauge, where the MSL value is derived from 13 years observation period from 1984 to 1996.

3.3 Eustatic sea level changes

The term eustasy, introduced by Suess (1888, in Tooley, 1993), describes the globally and simultaneously recorded vertical displacements of the sea surface, or sea-level changes (Daly, 1934, in Devoy, 1987), or simply, worldwide simultaneous changes in sea level. Fairbridge (1961), based on this concept, proposed a sea level curve taken from 'stable' areas from all over the world. A major revolution in thinking on the nature of eustasy took place with the inception of the International Geological Correlation Programme 61 (IGCP 61) that ran from 1974-1982. The project which aimed to establish a graph of the trend of mean sea level during the past 15,000 years (Tooley, 1982a), has led to the awareness that there is no such universal eustatic curve that is applicable worldwide. One of the main reasons is the discovery of deformation of the geoid's relief and redistribution of the water masses over the earth (Morner, 1976, 1980, 1987). The geoid is the equipotential surface of the earth's gravity field. The real ocean surface or the equipotential surface of the geoid is rough and uneven; there is a 180 m sea level difference between the geoid's hump and the geoid's depression with respect to the earth's centre (Morner, 1976). Sea-level variations are modified by many local, regional and global factors because of the deformation of the earth surface and its geoid by changing ice and water loads, and that no part of the earth's crust can be regarded as wholly stable (Clark et al., 1978; Kidson, 1982).

Table 3.1. Tide levels

		SUPRATIDAL ZONE
Extreme High Water	EHW	
Mean High Water Spring	MHWS	
Mean High Water Neap	MHWN	
Mean Sea Level	MSL	INTER-TIDAL ZONE
Mean Tide Level	MTL	
Mean Low Water Neap	MLWN	
Mean Low Water Spring	MLWS	
Extreme Low Water	ELW	
		SUBTIDAL ZONE

(Note: MSL may be lower than MTL (Plassche, 1986a))

3.4 Isostasy

Isostasy refers to the condition of equilibrium established by the earth's lithosphere, which essentially 'floats' on the asthenosphere (Fairbridge, 1983). In other words it is a state of balance which the earth's crust tends to maintain or to return to if anything occurs to upset that balance, so that depression in one locality will be compensated for by a rise in the crust elsewhere. Changing levels of land and sea reflect the interplay between two major elements: eustatic and isostatic processes. The respective growth and decay of the vast continental ice sheets during the Quaternary resulted in abstraction and release of water from and to the ocean basins. Not only are there large eustatic variations of sea level associated with the transfer of mass from the ocean to the ice sheets and back again, but there are pronounced isostatic variations associated with the deformation of the earth induced by surface loading. Global sea-level changes that result from the growth and decay of the ice sheets are termed glacial-eustatic changes. Similarly crustal deformations caused by ice sheet and water loading and unloading are referred as glacial-isostasy and hydro-isostasy respectively (Peltier, 1987). Changes in sea level that take place through the interactions of these and other factors are known as relative sea level changes, which essentially are local in effect.

3.5 Mechanisms of sea level change

The mechanisms that produce sea level changes are complex. It requires the explanation of among other factors earth's rheology, eustasy and isostasy. The variables and contributing factors include glacio-eustasy (eustatic changes related to the accumulation and wasting of land-based ice), geoidal-eustasy (distribution of ocean water under the influence of gravitational forces), tectono-eustasy (earth movements), glacio-isostasy (isostatic changes following shifts in surface loads such as ice), hydro-isostasy (water) and sediment-isostasy (Morner, 1976; Kidson, 1982). In addition, the steric effects produce changes in sea level from changes in water density due to short-term disturbances of the sea surface through variations in air pressure, ocean temperature or salinity (Woodworth, 1985; Devoy, 1987). Shennan et al. (2000b) noted various factors that operate at the coast and within estuaries also influence the registration of relative sea level changes in the sedimentary record. The local scale factors include modifications in the tidal regime along an estuary, relationship between freshwater table and tide levels and changes in the elevation of the sediment recording a past sea level since the time of deposition.

Geophysical predictions of global changes in postglacial sea level have been modelled by Clark et al. (1978), where the surface of the earth is subdivided into six regions, each of which has a characteristic form of postglacial relative sea-level history. The hypothesis is based on the calculation of the earth model response to melting of postglacial ice sheets of the Northern Hemisphere and the Antarctic (Clark et al., 1978; Clark and Lingle, 1979). Emerged beaches are predicted in four zones, which may form even at considerable distance from the ice sheets, while in the remaining zones submergence is dominant with no expected emerged beaches. Large areas including the southeast Asian region are classified in Zone IV, the 'oceanic submergence' zone, where no Holocene emerged beaches are predicted.

Peltier (1987) stressed the glacial isostatic adjustment (GIA) process as the explanation for why relative sea level continued to change even after many millennia since the last glacial ice sheet had completely disappeared. This is due to the extremely high value of the effective viscosity of the earth's mantle, the viscosity governing the rate at which mantle material flows in the process of restoring the deformed shape of the earth to one of gravitational equilibrium (Peltier, 1998). The two individual elements that contribute to the observed relative variation of level are the local radius of the solid earth or the absolute level of the surface of the sea (the geoid) relative to the centre of mass of the planet (the geocentre). To predict the variations in the relative level of the sea that accompany the ice age cycle of glaciation and deglaciation, the expression called the sea level equation is used (Peltier, 1998). The relative sea level history S (θ,λ,t), at latitude θ and longitude λ is given by;

$$S(\theta,\lambda,t)=C(\theta,\lambda,t)[G(\theta,\lambda,t)-R(\theta,\lambda,t)]$$

where,

$C(\theta,\lambda,t)$ is the 'ocean function', which by definition is equal to unity where there is ocean and zero where there is land,

$G(\theta,\lambda,t)$ is the geoid of classical geodesy defined by the surface of constant gravitational potential that is coincident with mean sea level (MSL) over the oceans,

$R(\theta,\lambda,t)$ is the local radius of the solid earth.

Peltier (1998) presented predictions of the relative sea level history that should be observed from sites at the equatorial Pacific Ocean and its margins, formerly called the 'far-field', based on the ICE-4G model of the last deglaciation event of the current ice age (Peltier, 1994) and the VM2 viscosity model. Satisfactory resolution from the coral-based records and predictions are observed especially with respect to amplitude and timing of the mid-Holocene high stand in the many Pacific islands and the subsequent predicted sea level fall.

3.6 Sea level index points

The sea-level index (SLI) point, basic to sea level investigation, is commonly described by its four attributes: geographical location, altitude, age and tendency. The sea-level index point is derived from sea-level indicators, which as illustrated in Plassche (1986b), are diverse and range from corals and reefs, marine molluscs, coralline algae, vermetid gastropods, beach rocks, botanical remains, foraminifera, diatoms, ostracods, shell middens, submerged forests, to marine notches, coastal deposits and barrier sands. Pirazzoli (1996) discusses sea-level indicators from archaeological remains and historical data. In north-west Europe and mainly in Britain, intercalated peat with marine clastic sequences and biostratigraphic analyses of the sea-level indicators have contributed greatly to Holocene sea-level studies (Jelgersma, 1966, 1979; Tooley, 1976, 1978; Shennan, 1982a,b, 1986a; Shennan et al., 1983, 1995a,b, 2000; Long, 1992; Long et al., 1998; Zong 1997, 1998; Zong and Tooley, 1996; and others). The fossil coral reefs from Barbados, and the Huon Peninsula, Papua New Guinea, have enabled the reconstruction of sea-level records spanning the LGM that even extend into the last interglacial period (Bloom et al., 1974; Fairbanks, 1989; Bard et al., 1990; Chappel and Polach, 1991; Chappel et al., 1996).

The terms transgression and regression have been used in a variety of contexts, and as stressed by Shennan (1982a,b) and Tooley (1982b), their improper used has led to much confusion. This has posed difficulty in correlating the results of different researchers. A marine clay layer overlying a peat bed is termed transgressive overlap, while the reverse is a regressive overlap. The usage is purely descriptive without implying a rise or fall in sea level. Both the transgressive and regressive contacts are two types of sea-level index points. Streif (1979), who correctly applied the usage in the Strait of Malacca study noted,

> "The regressive overlap of a semi terrestrial facies of the supratidal zone (peat) over marine or brackish facies of the intertidal zone (mangrove) was observed in a lot of borings... The height of these overlaps gives the local limiting value for sedimentation under marine influence. It needs not represent the onset of a fall in sea level. The regressive overlap can also occur during phases of still stand or slowly rising sea level....".

The sea-level index point tendency concept records the increase or decrease in the water level or salinity of the index point (Nelson et al., 1996). The local tendency reflects the movement of marine influence towards or away from the site, described as positive or negative tendency respectively, but does not necessarily imply a rise or fall in sea level. The application of biostratigraphic analyses is essential to ascertain the sea-level tendency established from a lithological interpretation. Nelson et al. (1996) cited examples of paleoecological changes within a lithological unit indicating either positive or negative sea-level tendency. A positive tendency may be indicated from pollen assemblages in the peat that suggest a shift from wetland to salt-marsh, while, for example, a negative tendency from diatom assemblages in an estuarine mud showing a change from marine to brackish-freshwater conditions. Nevertheless both tendencies, a negative and positive, could be found at a similar index point, as indicated by Shennan et al. (2000) in thin peat layers in northeast England. The application of the sea-level tendencies concept and using similar methods of data collection permit meaningful correlation of sea-level chronologies within and between areas. Shennan (1982a,b, 1986b) and Shennan et al. (1983) correlate dominant tendencies between rising and subsiding areas of Fenland in the northwest England and Tay Estuary in Scotland, from detailed analyses of the frequency of radiocarbon dated index points.

3.7 Indicative meaning

The indicative meaning of a dated sample refers to the altitudinal relationship of the local environment in which it accumulated to the contemporaneous reference tide level (Plassche, 1986a; Plassche and Preuss, 1978; Shennan, 1982a, 1986b). Since sea level curves could be derived from more than one type of index point, and to allow for comparisons between areas, each dated sample is related to a reference tide-level. The latter may not be constant and the interpretation depends on the accuracy of both the indicative range of the dated sample and tide level to which the dated sample is referenced. The indicative range is the vertical range of uncertainty in the indicator's relation to the reference water level, which commonly is the MHWS or MHW, because intertidal peat, often with distinctive assemblages of fossils, accumulates at or below the levels. Table 3.2 shows the indicative range and reference water level for commonly dated materials from the Fenland (Shennan, 1986b).

Shennan (1986b) stressed four main points in establishing the indicative ranges of the samples used:

1. The indicative meaning is dependent on the type of stratigraphic overlap under consideration.
2. The reference water level for each type of indicator should be given as a mathematical expression of tidal parameters, rather than a single tide level ± a constant factor.
3. The indicative range can be reduced by dating the level at which the pollen, diatom, macrofossil and stratigraphic evidence reveal a change in the sedimentary environment.
4. The accuracy of reference tide-levels must be assessed.

In addition, the indicative meaning could also be assessed using the microfossil ‘transfer function’, which establishes the relationships that exist between assemblages of species and the ecological conditions which control them, in this case the altitude or water level, or flooding duration, as has been developed by Horton et al., (1999), Zong and Horton (1999) and Gehrels (2000). The transfer function clearly has important implications, enabling easier measurement of the indicative meaning for establishing continuous records of relative sea level change or sedimentation.

Table 3.2. The indicative range and reference water level for commonly dated materials from Fenland, UK (after Shennan, 1982a).

	Indicative Range	Reference Water Level
Phragmites or monocot. peat:		
-directly above saltmarsh deposit	20 cm	((MHWST+HAT)/2)-20 cm
-directly below saltmarsh deposit	20 cm	MHWST-20 cm
-directly above fen wood deposit	20 cm	MHWST-10 cm
-directly below fen wood deposit	20 cm	((MHWST+HAT)/2)-10 cm
-middle of layer	70 cm	infer from stratigraphy
Fen wood peat:		
-directly above *Phragmites* or saltmarsh deposit	20 cm	(MHWST+HAT)/2
-directly below *Phragmites* or saltmarsh deposit	20 cm	MHWST
Basis peat:	?80 cm	MTL to MHWST

3.8 Stratigraphy

Sea level studies derived from sedimentary depositional sequences are primarily dependent on the lithostratigraphy. Coastal deposits that show intercalated peat and marine sediments form the best indicators. Biostratigraphy, microfossil and sratigraphic analyses, define the precise nature of the transgressive or regressive processes. Stratigraphic correlation, including litho-, bio- and chrono-, enables differentiation between local or regional factors to be established.

3.9 Microfossil analyses

Microfossil analyses are indispensable in sea-level studies, especially to ascertain the sea-level tendency indicated from a lithological interpretation. The methodology has been widely applied in northwest Europe and lately in north America (Tooley, 1976, 1978; Scott and Medioli, 1978; Smith et al., 1983; Palmer and Abbott, 1986; Shennan, 1986a; Long, 1992; Smith et al., 1992; Robinson, 1993; Shennan et al., 1994, 1995a, 1996, 2000; Gehrels, 1994; Nydick et al., 1995; Gehrels et al., 1996; Nelson et al., 1996; Zong and Tooley, 1996; Dawson and Smith, 1997; Zong, 1997, 1998; Long et al., 1998; and others). In active margin coasts of the Pacific northwest, Long and Shennan (1994) stressed the importance of microfossil analyses for differentiating the seismic versus aseismic and local verses regional changes in sea level recorded in the biostratigraphic column.

3.9.1 Pollen analysis

The paleoecological significance of pollen and spores in inferring former environmental conditions is well known (Birks and Birks, 1980). The pollen and spores obtained from stratified sequences of sediments provide records of vegetational change through time.

The ability of pollen analysis to differentiate between terrestrial and marine deposits in coastal sediments has been known for some time. As a matter of fact, pollen analysis has been recognised as one of the earliest techniques in sea level investigations. In Britain, its application for sea level study could be traced to Godwin (1940), who drew together stratigraphical, palynological and archaeological data from the Fenland and showed how relative changes in sea level had affected sedimentation and vegetation history in the area. The insistence of a consistent methodology in sea level studies (Shennan, 1992) and the significance of the indicative meaning concept have made pollen analysis among the important microfossil techniques in Holocene sea level investigations (Shennan, 1986a; Shennan et al., 1994, 1995a, 1995b, 1996, 2000; Long et al., 1998).

Vegetation zonation in the coastal environment reflects the adaptation of certain types of plants to the prevailing coastal conditions. The apparent correlation of the coastal vegetation pattern with elevation (i.e. tide levels) has made it useful as a sea-level indicator. In temperate coastal regions, salt marshes commonly exhibit a distinct plant zonation that is controlled by tolerance of plants to tidal inundation and inter-specific competition. Similarly, in tropical coasts, vegetation zonation from the intertidal to subtidal is generally displayed by salt-tolerant mangroves grading into brackish *Nypa* swamps and to freshwater communities. Ellison (1989) stressed the significance of mangrove sediments as sea level indicators and applied features established from a modern analogue to interpret fossil pollen patterns in Tonga, southwest Pacific. However, the drawback of the study is that it does not identify the sea level index points and also fails to quantify the indicative meaning. The latter were similarly not identified in studies from Australia (Woodroffe et al., 1985, Harvey et al. 1999), Bangladesh (Islam and Tooley, 1999), Hong Kong (Yim, 1999), West Indies (Woodroffe, 1981) and Venezuela (Rull et al., 1999).

3.9.2 Diatom analysis

Diatoms are microscopic unicellular plants (algae) occurring in large numbers in fresh and marine waters, also in moist soils and other wet substrates. They live in naturally illuminated environments as plankton or attached to a substratum. Diatoms have been used for studies of Quaternary sea-level changes in north Europe since the last century. It has long been recognised that many diatom species have depth and in particular salinity preferences: the fresh, brackish and marine diatoms. Palmer and Abbott (1986) further elaborate the usefulness of diatoms, in that they are widespread in natural aquatic environments, many species prefer specific salinity conditions, the silica constituting the valves is relatively resistant to chemical alterations after burial, and diatoms are often preserved with radiometrically dateable carbonaceous material.

Diatom assemblages found in cores in coastal sediments usually represent nearby microfloral populations. Zong (1997) identified indicative diatom groups in relation to reference tidal levels, vegetation zones and sedimentary characteristics to reconstruct the marsh surface elevations at Roudsea Marsh, northwest England. In addition the salinity class (egs. polyhalobous, mesohalobous, oligohalobous and halophobous) and life form (egs. planktonic, epiphytic, episammic, and aerophilous) are used to infer paleo water salinity and sediment characteristics.

3.9.3 Foraminifera analysis

Certain foraminiferal assemblages are good sea-level indicators since their primary controlling factor appears to be elevation above mean sea level (Scott and Medioli, 1978). These assemblages are known to occur in the intertidal zone especially occupying the marsh environments within narrowly defined vertical zones, some of which have less than 10 cm in total vertical range (Scott and Medioli, 1986; Williams, 1994; Horton et al., 1999). Nonetheless, Rijk and Troelstra (1997) indicate that the distribution of foraminiferal salt marshes assemblages in the Great Marshes, Massachusetts, USA, does not show a vertical zonation with respect to mean high water. They conclude that surface foraminiferal study is indispensable in assessing its value as paleo-ecological indicators, since each salt marsh has its own foraminiferal fingerprint and characteristics.

3.10 Radiocarbon dating

Radiocarbon (^{14}C) dating is the technique most commonly used to date samples in sea level studies. The basic principle of the method is that the ^{14}C (the unstable C isotope and thus radioactive, though weakly) concentration in the atmosphere is constant and thus ^{14}C level in all living organisms is also a constant. In 1946 an American scientist, Willard Libby, discovered the existence of ^{14}C in living matter (Bowman, 1990). An animal or plant upon dying ceases to participate in the C exchange with the biosphere and no longer takes in ^{14}C. The ^{14}C level thence falls at a rate that is determined by the law of radioactive decay. Hence organic materials like wood, charcoal, seeds, leaves, resin, lichen, peat, humus, bone, marsh gas, ivory, tissue, horn, hair, shells, secondary carbonate, soil and sediment, as well as groundwater and ice, are suitable for ^{14}C dating (Geyh and Schleicher, 1990). The maximum age determined from the conventional ^{14}C dating is in the region of 40,000 years.

A further advance in the ^{14}C dating method concerns the application of accelerator mass spectrometry (AMS), which directly measures the ^{14}C atoms relative to ^{13}C or ^{12}C atoms in the sample, rather than counting β decays as in the conventional dating technique. The advantage of AMS technique is that only very small samples are required, by a factor of about 1000 times smaller, as compared to the latter (Bowman, 1990; Hedges 1991). This means that the sea level indicator dated using the AMS method has the potential for the indicative meaning of the sea level index point better refined and the indicative range reduced.

^{14}C results are always given in uncalibrated years BP, where 0 BP is defined as AD1950. Calibrated ^{14}C dates (sidereal age) are very significant when absolute timescales and rates of change are required (Bartlein et al., 1995). Pilcher (1991) showed that uncalibrated dates of 4100 and 4090 BP which appear synchronous give calibrated ages of anywhere in the range of 4830 and 4470 cal BP, so that one sample could be at least 300 years older than the other. The standard calibration procedure that is now conventionally employed to convert ^{14}C age to sidereal age is that described by Stuiver and Reimer (1993) and Stuiver et al. (2000).

By convention ^{14}C dates are always quoted with ± one standard deviation. The error term means that there will be about 35% probability that the real date will lie outside this range. For practical purposes the ± figure is doubled in order to obtain the (approx.) 95% confidence limit (Pilcher, 1991).

3.11 Sources of error

In presenting results of sea level studies, errors that arise during its various stages of procurement need to be considered. The data acquired should be standardised for comparability and correlation, especially in identifying regional sea level movement. Some of the errors are quantifiable but others are limited to the current state of knowledge. The error sources are considered below.

3.11.1 Measuring altitude of stratigraphic boundaries

Shennan (1982a, 1986b) identified sources of errors when measuring the altitude of stratigraphic boundaries. These include errors that arise during measurement of depth in a borehole, levelling of the site to benchmark and the benchmark accuracy.

Altitudinal errors during coring and levelling could be respectively minimised if precautionary measures are taken, such as ensuring that the coring is vertical and setting the levelling instrument correctly. When using levelling instrument, the spirit bubble should be correctly centred, the levelling staff vertically positioned and short-distance surveying should be undertaken in levelling from site to the benchmark. Shennan (1986b) noted that the accuracy of levelling is dependent on the length of the survey line and varies for the order of benchmark and levelling. In England, for local comparison, benchmarks are accurate to ±0.01 m relative to each other, but relative to Ordnance Datum (OD) Newlyn, Cornwall (UK national reference datum level) the accuracy for England and Wales is ±0.15 m, and ±0.20 m for Scotland (Shennan, 1986b). In peninsular Malaysia the national height control datum is based on the MSL value at Port Kelang. Shennan (1986b) also indicated that the accuracy of the estimated altitude of a stratigraphic boundary is dependent on sampling density and the local stratigraphic roughness. To avoid altitudinal errors in the order of ±0.30 m, borehole density equal to 30 m grid may be required. Table 3.3 summarises the errors from the measurements of altitude based on data from the Fenland, UK.

Table 3.3. Errors arising from the measurements of altitude of stratigraphic boundaries (from Shennan, 1982a).

Identification of boundary	±0.01 m
Measurement of depth - hand coring	±0.01 m
Measurement of depth - commercial U4	±0.05 m
Measurement of depth - commercial (disturbed)	±0.25 m
Compaction & extrusion of piston cores	up to 0.06 m
Duits gouge sampler (not for ^{14}C samples)	up to -0.20 m
Angle of borehole	up to +0.04 m
Levelling to benchmark	up to ±0.02 m
Accuracy of benchmark to OD	±0.15 m
Sampling density - 1 borehole per 2 m^2	c. ±0.06 m
Sampling density - 1 borehole per 5400 m^2	c. ±0.14 m (σ)
	$\therefore$95% limits = ±0.30 m

3.11.2 Indicative meaning

The relationship between fossil sea level indicators and a contemporaneous reference tide level may not be known exactly and fixing the indicative meaning to a particular reference tide level could contribute to an inaccurate sea level estimation. Tidal variations within an area limit the accuracy to which former sea levels can be estimated (Redfield, 1972; Kidson, 1986; Plassche, 1986a; De Rijk and Troelstra, 1997). Redfield (1972) showed that the elevation of high and low water was not uniform across the Great Marshes, at Barnstable, Massachusetts, northeast USA. Similarly, Kidson (1986) indicated that in the Bristol Channel the height of High Water Spring Tide (HWST) above O. D. increases by more than 3 m from the mouth of the Channel to the head of the estuary. The simulation model for Flandrian coastal stratigraphy of Allen (1995), based on conditions in the Severn Estuary, noted that the indicative meaning of peat-based sea-level indicator is not fixed but varies within the tidal frame. An organic-rich facies can appear at various levels within a wide range of elevations, normally well above MHWST and generally closest to HAT, in accordance to the rate of organogenic sedimentation.

Selection and identification of appropriate indicators affect the precision with which the local water table can be established. The sea level indicator determines both the indicative meaning and range of the sea level index point. The precise identification where change had occurred, as summarised from the litho-, bio-, and chrono- stratigraphical information, reduces the error range of the sea level index points.

Zong and Horton (1999) indicated a more precise measurement of the indicative meaning using the diatom-based transfer function as compared to the qualitative assessment. Gehrels (2000) noted strong correlations between the geologic records and the observational data. Horton et al., (1999) and Zong and Horton (1999) nevertheless, mentioned the necessity to exercise caution when applying the transfer functions since several characteristics within the contemporary and fossil data may affect the accuracy of the tide level reconstructions (Horton et al., 1999; Zong and Horton, 1999).

3.11.3 Tidal range

In most Holocene sea level investigations the altitude/age plots assumed that the paleotidal regime has been similar to the present day and the paleotide has behaved in a constant manner throughout the period. Often this is not the case since spatial variation in the height of the tide are the results from the interaction of earth rotation, shape and depth of the ocean-coastal water and coastal-offshore zone configuration (Devoy, 1987). Paleotidal studies and modelling indicate variations in the tidal regime as illustrated in, among others, Scott and Greenberg (1983), Roep and Beets (1988), Austin (1991), Hinton (1992, 1995) and Gehrels et al. (1995). Scott and Greenberg (1983) reproduced paleotidal regimes over the last 7000 years from both sea level data and numerical models in the Bay of Fundy, Canada. The tidal amplitude showed an increase by as much as 5.5 m in the period 7000-2500 BP, with an average increase of 1-2% with each 1 m rise in sea level. Further, Gehrels et al. (1995) indicated that the principal lunar semi-diurnal component (M_2) of the tidal range constitutes an important contributor to the Holocene rise of mean high water in the Gulf of Maine/Bay of Fundy area. The M_2 showed an increased tidal range, from

54-59% (as % of the present range) at 7000 BP to 98% at 1000 BP. Meanwhile, Roep and Beets (1988) used sedimentary structures in the coastal barriers in western Netherlands to estimate the paleotidal levels, which suggests tidal amplitude of about 2 m between 4500-3000 cal BC and about 1.5 m for the last 2000 historical years.

Based on the analyses of the recent tidal records, Woodworth et al. (1991) inferred long-term changes in the tidal regime in the northwest European continental shelf. Woodworth et al. (1991) explained the causes as: firstly, from the changes in the deep ocean tides bordering the shelf and secondly, the shelf itself, with changes in its own shape or depth or in the major river estuaries and inland seas (e.g. Wadden Sea) which connect to it. In the first case this could stem from long-term changes in the tidal potential, arising from variations in the orbital elements of the Sun and the Moon, or from long-term changes in the shape or depth of the major ocean basins or in the rate of global tidal dissipation.

3.11.4 Sediment Compaction

Compaction is an important factor in sea level studies. It is the process of slow expulsion of pore fluids and the reduction of voids within a sediment prism as a result of stresses due to overburden load (Greensmith and Tucker, 1986). It is generally synonymous with the term consolidation, the physical process of gravitational compaction, as commonly used by civil engineers. Paul and Barras (1998) prefer the geotechnical usage 'compression', which is essentially stresses dependence compaction, for the reduction in volume due to an increase in effective stress.

All sediments undergo compaction and consolidation with time, the rate of which depends on various factors including drainage and load, composition, structure and mineralogy (Jelgersma, 1966; Tooley, 1978; Greensmith and Tucker, 1986). Holocene coastal sediments are commonly lithologically diverse. Peat and related sediments, from which the sea level index points are generally derived, are probably the most affected as compared to siliceous gravels and sands. Allen (1999) indicated that autocompaction, the consolidation of a column of sediment due to its own weight, significantly and variably depressed index points derived from intercalated peats and other organic materials. The numerical simulation demonstrated that autocompaction showed its strongest influence in peat samples from transgressive and regressive overlaps, which will produce sea level curves that lie below their true altitude. The mathematical modelling of autocompaction by Pizzuto and Schwendt (1997) indicated that rates of autocompaction of multilayered mud and organic-rich mud were close to 1 mm/year during most of the past 6000 years, implying a maximum consolidation of 2.3 m at a depth of 7 m at Wolfe Glade, Delaware. Nevertheless the approach was based on a variety of assumptions that are difficult to verify (Pizzuto and Schwendt, 1997). Bloom (1964) estimated basal peat compaction at Clinton, Connecticut, by dating both the lower (compaction free) and upper transgressive peat contact and plotted in an age/altitude graph. The estimated compaction is 13-44% in 7000 years. Haslett et al. (1998) dated the transgressive peat contacts (may be regarded as basal peat), which basically reveal similar ages (3.25-3.38 ka BP). Based on radiocarbon dates and presumed pre-compaction altitude Haslett et al. (1998) interpreted a maximum compaction of 2.2 m since ~3300 BP for a peat layer from the Somerset Levels, southwest Britain.

Compaction is a continuing debate in sea level studies since there is yet no common solution of its obvious deficiency. Is has been envisaged that sea level index points derived from basal peats are probably seen as the solution to problems associated with compaction (Plassche, 1990; Denys and Baeteman, 1995; Kiden, 1995). The compaction-free basal peats, commonly overlying a consolidated formation could be directly translated as the sea level index points. However it is often difficult to define the indicative meaning of basal peats, since they are commonly of freshwater origin (Bloom, 1964; Haslett et al., 1998), and the thickness of the peat layer itself implies compaction correction.

3.11.5 Radiocarbon dating

Radiocarbon dating, even though is a well-established method of dating the sea level index points, poses inherent and incidental problems and uncertainties. Mook and Plassche (1986) explained the intrinsic aspects to the associated standard deviation conventionally quoted with ^{14}C ages and the variations in the natural ^{14}C concentration of atmospheric CO_2, which may cause the time ranges quoted for ^{14}C dates to be significantly smaller or larger than the true periods. Further problems may arise from contamination of the sample material.

The assumption of constant ^{14}C activity of atmospheric CO_2 is one of the criteria of the dating technique. ^{14}C measurements of dendrochronologically dated tree rings showed that the assumption is not entirely true (Mook and Plassche, 1986; Suess 1986; Bowman, 1990; Geyh and Schleicher, 1990). The explanation for the deviations of the ^{14}C time-scale from the solar time-scale is classified into long-, medium- and short- term trends with respective periods of 9000 years, several centuries ('wiggles'; Suess 1986) and the 11 year sunspot cycle. The correction due to isotopic fractionation, the phenomenon in which $^{12}CO_2$ is preferentially taken up over $^{14}CO_2$ during photosynthesis, has to be applied in some plant specimens. The reservoir correction of about 400 years has to be applied for marine carbonates due to the apparent age of surface ocean water. Also, contamination contributes to the uncertainties of the radiocarbon dates. This is associated with contamination from older or younger organic matter, the quantity of the sample sent for dating, treatment, handling and storage of samples. Wohlfarth et al. (1998) noted that long-term storage of wet macrofossil samples have a significant effect in producing anomalously young ages of AMS radiocarbon dates.

3.12 Sea level interpretation

Holocene sea level studies are generally presented as age/altitude plots, commonly referred to as sea level graphs/curves. As discussed earlier, until the late 1970's the general debate centred around the concept of eustatic sea level change. Two major sea level interpretations were predominant. One school of thought envisaged a fluctuating sea level rise with subsequent mid- to late- Holocene higher than present (e.g. Fairbridge, 1961; Morner, 1971; Tooley, 1976). The explanation for the fluctuating curve is interpreted from the nature of sea level rise, which is dominated by phases of marine transgression and regression. The alternating peat and clay layers, as reflected in the stratigraphy represents actual changes in sea level. In addition, microfossil analyses were also conducted (Tooley, 1976). On the other hand, others interpreted Holocene sea level change as a smooth exponential rise to the present (e.g. Bloom and Stuiver, 1963; Jelgersma, 1966; Kidson and Heyworth, 1973; Belknap and Kraft, 1977). Most of the smooth sea level rise exponents based their data from the basal peats. The reasoning assumes a causal relationship between the inception of peat growth, rising ground water and approaching marine conditions as sea level rises (Tooley, 1978). Further, the 'smoothers' assume that each sea level index point may deviate slightly from true sea level, assigned statistical errors to ages and depths, and thus form best-fit curves, either visually constructed or computed (Belknap and Kraft, 1977). Nonetheless, the validity of the Bristol Channel sea level index points (Kidson and Heyworth, 1973), are subject to criticism (Haslett et al., 1998). Subsequent to IGCP 61, the emphasis of sea level studies has stressed the study of local and regional areas. The geoidal sea surface and geoidal changes of Morner (1976) and numerical modelling of the last postglacial sea level changes of Clark et al. (1978) have contributed to the explanations of variations in Holocene sea levels observed from different places.

The varying interpretation of sea level results stems from the techniques in which sea level studies are approached and the wide attention from various disciplines that the subject has received (e.g. archaeology, geomorphology, geology, geophysics, oceanography, coastal engineering, geochemistry, ecology). Tooley (1978) noted that sea level studies had lacked an accepted methodology while Shennan (1982a) pointed to accurate operational definitions. Shennan et al. (1983) applied tendency analysis as an alternative approach in detecting the timing of increase or decrease of marine influence, and as a correlating scheme within and between areas. The concept uses only age and tendency of index points, ignoring altitude.

Shennan and Tooley (1987) pointed that a single line or an age/altitude graph is a poor summary of sea level changes if the variation in data points is not known. Thus the accommodation of errors in sea level reconstruction probably enhanced the estimate of the sea level trend. This could be achieved and refined by considering the local litho-, bio-, and chrono- stratigraphy, contemporary environment analysis, and errors that arise from the estimation of the sea level index points. Furthermore, the interpretation of changes in sea level is scale dependent. Plotting of the sea level index points in an age/altitude graphs for time scales in the order of 1,000 years or 10,000 years will obviously differ in terms of the accuracy required. In the former the reconstruction of low amplitude fluctuations could still be generalised but in the latter the alternations of periods of positive and negative tendencies may become insignificant.

CHAPTER 4

RESEARCH METHODOLOGIES

4.1 Introduction

This chapter reviews sampling strategy, site identification and selection, the fieldwork undertaken and its approach, laboratory analysis and data treatment.

4.2 Sampling strategy

The approach adopted here is to investigate the relationship between contemporary microfossils found in a range of environments (including habitat and tidal elevation), and the application of this knowledge to the interpretation of fossil microfossil sequences, which is then used to interpret the fossil situation.

4.2.1 Pollen dispersal and sedimentation

Microfossil data, particularly that derived from pollen, need to be interpreted with care. The transport of pollen to a depositional site, may occur by many processes; by streams and surface runoff, through the trunk space, above canopy and as rainfall component (Tauber, 1965, 1977), and may be derived from local and regional sources (Janssen, 1973), and also as the gravity component (Jacobson and Bradshaw, 1981). It is known that pollen deposited at a given locality does not directly reflect the vegetation of the source area (Birks and Birks, 1980; Waller, 1994). Turner (1964), nonetheless, analysed surface samples at different distances from a line of pine trees across a raised bog and showed that high *Pinus* values occurred near the source of the pine trees, with exponential fall off to low values over a relatively short distance of 400 m (Fig. 4.1). Andersen (1970) and Bradshaw (1981) showed that within closed forests, pollen does not travel beyond 20 to 30 m from its source. Theory and experimental evidences suggest that pollen dispersal is leptokurtic, i.e. the curve of number of grains deposited when plotted against distance from the source, will show the former to initially fall very rapidly but become almost constant with distance (Moore and Webb, 1978; Birks and Birks,

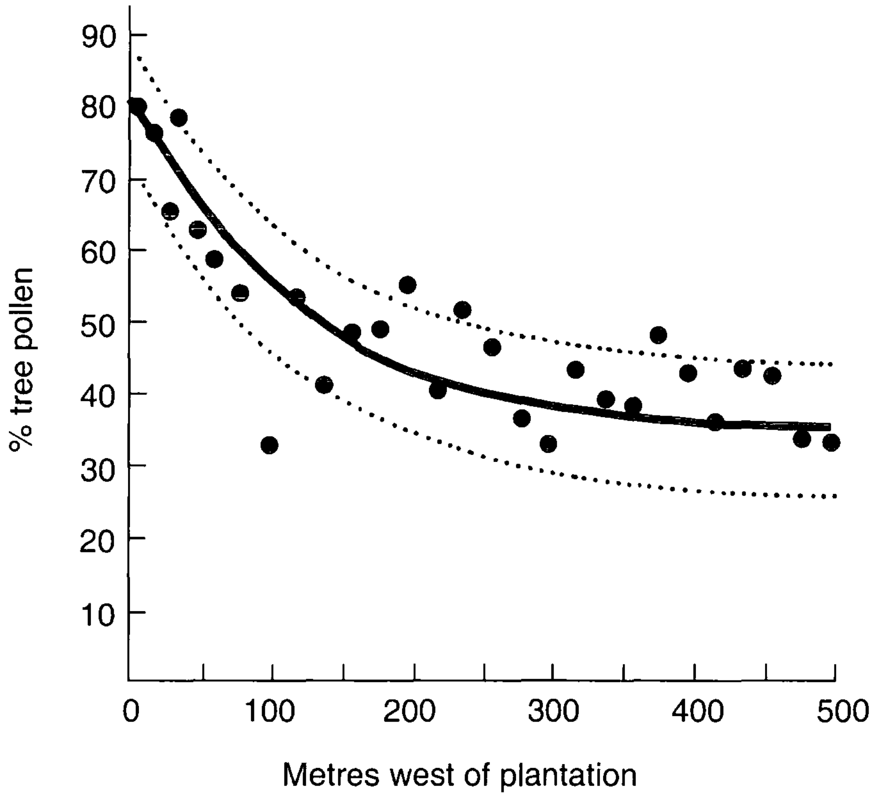


Fig. 4.1 *Pinus* pollen frequencies in surface samples, expressed as percentages of total tree pollen, from a transect west of Cameron's Moss plantation, together with the estimated curve $y(x) = a + \beta e^{\gamma x}$ and the 80% confidence limit on either side (after Turner, 1964).

1980). Over- and under-representation of pollen is quite a common phenomenon. Some taxa show a high pollen presence but are under-represented in the vegetation but others constitute important components of the vegetation but their pollen is low or even absent. This anomaly is due to the differences in pollen production and dispersal bias. Wind and animal pollinated plants show large disparity in their pollen records; generally the former is more common while the latter in lesser common or rare.

Shennan (1980, modified in Waller, 1994) modelled theoretical pollen dispersion within the Fenland (UK) coastal vegetation setting. In general, pollen distribution reflects its local surrounding vegetation. Higher pollen concentration occur near to sources while low values occur further away. Exceptions result from the well dispersed high pollen producer of the fen carr and the poorly dispersed upland tree taxa, with the former showing wider areal dispersion compared with the latter. However this model is yet to be tested since there is no modern pollen data from comparable coastal situations (Waller, 1994). The study from northwest Scotland (Shennan et al., 1995a) showed an important relationship between contemporary and fossil pollen of mainly *Plantago maritima*, Gramineae, Cyperaceae and *Calluna*, and their significance in Holocene sea level reconstruction. In the study of modern pollen distribution in marsh environments in the Mississippi Delta plain, Chmura (1994) further indicated that palynomorph assemblages are characteristic of salinity and depositional environments. Pollen assemblages here show close relation to the local vegetation that characterizes the four salinity zones: fresh, intermediate, brackish and salt.

4.2.2 Pollen deposition in mangrove environments

Muller (1959) describes the pollen distributions of a number of terrestrial and swamp plants, including the mangroves (*Rhizophora mangle* and *Avicennia nitida*), from extensive surface sampling of coastal and offshore sediments in the Orinoco Delta, Venezuela. *Rhizophora* pollen is shown to have ubiquitous distribution both landward and seaward of the parent source indicating prolific pollen production and dispersal, while *Avicennia* pollen coincides strongly with its source area. From similar surface sediment analysis, Caratini et al. (1973) describe the relationship between the modern pollen distribution and vegetation of a mangrove environment at

Pichavaram, southeastern India. The results do not show a direct relationship between the pollen assemblages and the vegetation. *Rhizophora* and *Sonneratia* show over-representation while *Avicennia* is under-represented. Grindrod (1985) reconstructs the history of mangrove and saltmarsh vegetation on a Holocene prograded chenier plain at Princess Charlotte Bay, northern Australia. The study involves modern pollen rain sampling, surface sediment and core sample transects. The results show that *Rhizophora*, *Ceriops/Bruguiera*, *Avicennia* and Chenopodiaceae form important locally deposited pollen types in the intertidal and supratidal sediments. The abundance of these pollen types relative to regional and long distance components clearly defines environments of deposition within the zoned mangrove fringe or on the saltmarsh flats. Major mangrove and salt marsh taxa display highly localised pollen dispersal, despite the potential for tidal redistribution. In a similar study, Behling et al. (2001) carried out modern pollen rain, surface sediment and core samplings in the mangrove in northeast Brazil. Using changes in proportions of the major tree taxa in the mangrove vegetation, *Rhizophora* and *Avicennia*, they observed that *Rhizophora* shows a constant high value within the mangroves. The modern pollen rain ratios of *Rhizophora* (R) to *Avicennia* (A) are calculated as 4:1 in *Avicennia* forest, 33:1 for mixed *Rhizophora/Avicennia* forest and 115:1 in *Rhizophora* dominated forest. Meanwhile in the surface sample from *Avicennia* forest the R/A ratio is 22:1. The pollen rain shows a close relation of the pollen assemblages to local vegetation, the mangrove, salt marsh and the restinga areas. Nevertheless, the sea level interpretation in the study has been erroneously depicted: firstly, because the elevation of the core sites was not levelled to the reference water levels; and secondly, the plot of Fig 7 of Behling et al. (2001) actually denotes mangrove sediment accumulation phases as opposed to sea level.

In the mangrove environments of peninsular Malaysia, it is known that many taxa thrive (Watson, 1928; Whitmore, 1972a; Ng, 1978, 1989), the more common being *Avicennia* (4 species), *Sonneratia* (4 species), *Bruguiera* (5 species), *Ceriops* (2 species), *Kandelia* (1 species) and *Rhizophora* (3 species). Even so, pollen analyses of mangrove and estuarine/shallow marine sediments reveal the common and persistent presence of mainly *Rhizophora* pollen types, but low or scarce counts for the other mangrove taxa (Haseldonckx, 1977; Hillen, 1986; Kamaludin, 1989). The common and widespread presence of *Rhizophora* has also been reported in mangrove environments elsewhere (Grindrod, 1985, 1988; Ellison, 1989; Caratini and Rajagopalan, 1992; Somboon and Thiramongkol, 1992; Tissot and Marius, 1992; Behling et al., 2001). *Nypa* is noted to be under-represented in the pollen records, in contrast to its abundance in the mangrove/back mangrove environments. Differential pollen production and dispersal bias (some are probably wind or insect pollinated) of the respective mangrove taxa, constitute the main reasons. It has been suggested that the main pollinator of *Rhizophora* is wind, while *Avicennia, Sonneratia, Bruguiera, Ceriops*, *Kandelia* and *Nypa fruticans* are mainly dispersed by animals such as birds, butterflies, moths, bees, insects and even bats (Tomlinson, 1986). In addition, factors such as pollen preservation after deposition (some pollen grains like Orchidaceae are not preserved in sediments due to their weak exine, which is easily decayed) and the size/shape of the pollen grains also determine the pollen representation in the sediments.

Apart from the agents of pollination, sediments, water and tides also play an important role in pollen dispersal and deposition within the mangrove and the coastal environments. Tidal inundation may mix local mangrove pollen with those from the surrounding areas. Mangrove sediments may be reworked by tidal currents and mixed by a range of biogenic agents causing considerable disturbance. Semeniuk et al. (1978) regarded mangrove sediments as a living soil, and suggested a variety of biotic interactions from nektonic, terrestrial and resident fauna, which potentially disturb the sediment. A cross-section through a mangrove soil will generally reveal living and dead root systems and other plant remains such as leaves and branches, and also burrows inhabited by living animals including clams, worms, crabs and fish (Fig. 4.2). Vertical mixing of sediments could reach 50 cm from the surface. Grindrod (1988) indicated the capacity of mangrove and saltmarsh sediments to retain pollen in a well preserved state seems to vary widely. The optimal conditions are most likely along muddy, low energy shores and where sediment accumulation, either inorganic or organic, is not excessive. Ellison (1989) stressed that pollen analysis from open-system intertidal and nearshore sediments do offer the sensitive record of the traditional closed systems of lakes and bogs. Ellison also suggested a close sampling of less than ±10 cm of the mangrove peat.

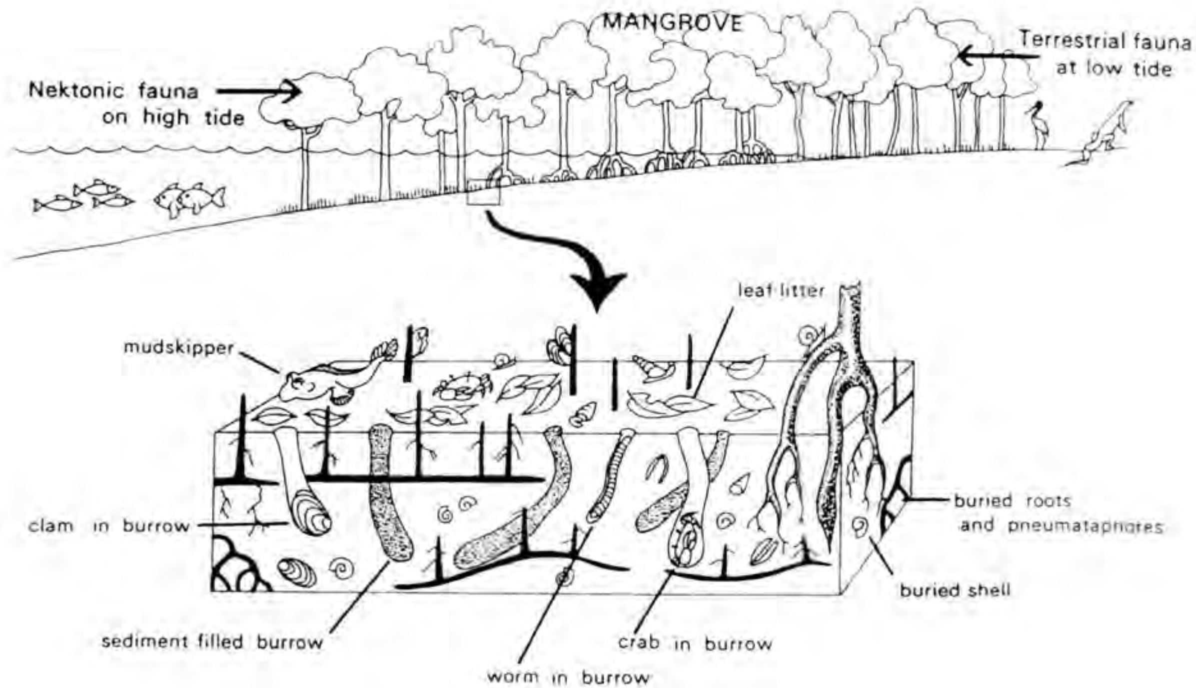


Fig. 4.2 Generalised illustration of a mangrove environment and its 'soil' (from Semeniuk et al., 1978).

4.3 Site identification

The criteria used to identify sites for this study include coastal geomorphology, lithostratigraphy and accessibility. The sites for this investigation are selected so as to represent, in a broad sense, peninsular Malaysia's main coastal types. As indicated earlier, in the peninsula, basically two coastal types predominate, each present in the west and the east coasts. Since the main objective is to reconstruct Holocene sea level changes, the sites to be selected should fulfil the main requirement of the study, that is the coastal sites should disclose stratigraphic changes as a result of the Holocene marine transgression or regression. The subsurface lithological record available from both the west and east coasts were then checked. Accessibility to the study sites was then assessed. Two factors are especially taken into account, location and distance between the study sites. Considering all the criteria mentioned the central peninsula was identified as the most suitable location for this study. Also, the selected sites, Kelang in the west coast and Kuantan in the east coast, are easily accessed by road from the logistics centre and base, the Department of Mines and Geosciences at Ipoh, Perak.

Since the study also deals with the contemporary environments, apart from subsurface information surface sampling sites were considered. The identification and selection of surface sampling sites was mainly done in the field, where limited survey of the coastal environments (within vicinity of the coring sites) was carried out. The contemporary environments sampled are presumed to be those similar to the fossil situations. Prior to fieldwork, site information is collected and assessed from the Quaternary geological literature, past drilling records, aerial photographs, topographical maps and tide tables.

4.4 Field investigation

Field investigation was undertaken from mid-June 1998 to late August 1998. This involved augering, lithologic description (logging), sampling and levelling. During the fieldwork, Holocene sediment samples were augered and logged while recent surface samples were collected from various representative coastal environments. The altitude of all the sampling sites, both the boreholes and surface samples, were levelled to the nearest benchmark (Figs. 4.3 & 4.4). Benchmark

Fig. 4.3 Benchmark by the roadside.

Fig. 4.4 Close-up of the benchmark of the Department of Survey and Mapping, Malaysia.

information was obtained from the Department of Survey and Mapping in Kuala Lumpur and Kuantan.

4.4.1 Sampling methods

Two types of samples were collected for the study, the augered/cored and surface samples. Coring was mainly conducted using the gouge, peat (Russian-type) and spiral (Edelman) augers/corers/samplers. The usage of a particular augering tool depends very much on the ground and subsurface lithological conditions. In surface sampling, only simple basic tools like a broad flat knife and small trowel, were used. Samples collected were properly wrapped, labelled and recorded. The samples were then carefully packed and transported (air-flown) to Durham.

The gouge sampler was most often used during the investigation. It provides a fast and effective means of sampling the Holocene sediments. Also the samples retrieved are generally undisturbed. Basically, the sampler is made up of the cutting blade (auger head), hooking device, the 'sleeve', extension rod and T-shaped handle. The auger head is 3 cm in diameter and 1 m length (similarly the extension rod). Sampling is done by vertically putting the sampler on the ground and pushing it to the required depth. The handle is then rotated through a 360° turn and the auger lifted out. By attaching the extension rod to the sampler the tool could also retrieve deep samples, up to slightly more than 10 metres depth. The sampler is best suited for soft silty and clayey sediments, but not sand, woody peat and hard clay. Common with all coring equipment, penetration often becomes more difficult with increasing depth. On occasion, sampling below the water table is quite difficult, the sediments tend to become watery and 'very loose'. Also, in using the gouge sampler care should be taken that the sediment retrieved is from the correct stratigraphic layer since it is quite common for the overlying sediments to stick to the upper part of the sampler, especially if the overlying layer is made up of sticky clay. In coring, the borehole should always be vertical. Shennan (1982a) noted that depending on the angle of the borehole, the errors associated with inclined coring could be up to 0.04 m.

The peat or Russian-type sampler, described in Jowsey (1966), is mainly used for sediment sampling. It consists of an anchored fin and the movable sampling chamber. The latter is a semi-circular cylinder measuring 50 cm in length and 5 cm diameter, with one end forming the sharp pointed edge that penetrates the sediment while the other end is connected to the T-shaped handle. Like the gouge auger, the peat sampler operates quite similarly, the difference being the latter is only rotated through a 180° turn during sampling. Before sampling proceeds, one needs to observe the alignment of the fin with regard to the sampling chamber so that when the sampler is rotated the required samples will be collected. There have been instances when the fin, which is supposed to be stationary, was forced to rotate. This could be due to incorrect fin and sampling chamber orientation when the sampler was rotated or turning the auger more than 180°. This had unnecessarily incurred some damage on the sampler whereby the sampling chamber became skewed.

Samples collected using the peat sampler are not disturbed compared to those collected with the gouge auger. This is because the samples remain enclosed within the sampling chamber throughout the process of sampling. The samples collected were then transferred to half-diameter PVC cylinders, sealed in polythene and labelled, noting the top and bottom of the core. Samples for all the analyses in this study (Figs. 4.5-4.7), including those submitted for radiocarbon dating were sampled using the peat auger.

The spiral or sometime called the Edelman auger was occasionally used during the course of the fieldwork. It functions mainly to penetrate the few cm of the top-most ground surface, which are sometimes rather hard. It is made up of the auger head and extended attachment to the T- shaped handle. It works by simultaneously turning and pushing the auger head on the ground. It is generally used to auger firm to hard clay layer of the surface and subsurface sediments. The sample retrieved using the tool is generally disturbed and unsuitable for analysis. In this study no sample for analysis was collected using the auger.

Surface sampling was made at various representative ecological environments. For each sample approximately 10 cm^3 (10cm^2 surface sample by 1 cm thick) were taken using the knife and trowel. Observed burrows or any surface contaminants (leaves, stems etc.) are avoided from sampling. The samples were then placed in plastic bags and labelled.

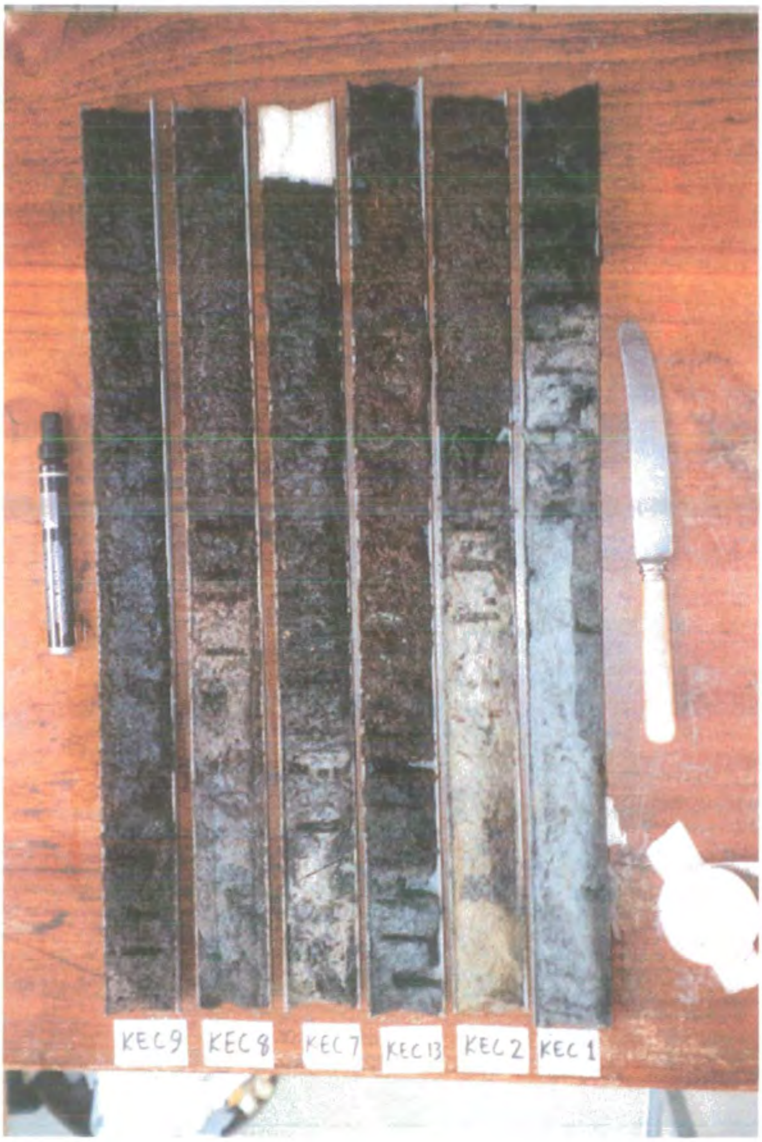


Fig. 4.5 Kelang core samples.

Fig. 4.6 Samples of core KUC15, Penor (north), Kuantan.

Fig. 4.7 Samples of core KUC12, Penor (south), Kuantan.

4.4.2 Lithostratigraphic description

It is important that lithologic description (logging) is accurately recorded since the accuracy of data collection will be reflected in the stratigraphic interpretation. Lithologic boundaries need to be appropriately defined and measured. In the field the description is made using common and accepted methodology (Long et al., 1999). Apart from the basic field tools a Quaternary scientist would also require additional assistance to aid in the field description like Soil Colour Chart, measuring tape, grain-size comparator, dilute hydrochloric acid, and eye lens. The borehole logs of this investigation are listed in Appendix 1.

In the study the lithology is described following Troels-Smith (1955) scheme of sediment description. The scheme is purely descriptive, flexible and does not involve consideration of the sediments depositional processes. A deposit is classified by three characteristics: the physical features (i.e. the appearance and mechanical qualities of the deposit), humicity (degree of decomposition of the organic substance) and component parts (nature and proportion of the elements of which the deposit is composed). The physical properties of a deposit include degree of darkness (nigror), stratification (stratificatio), elasticity (elasticitas) and dryness (siccitas). In describing the three main classes and their sub-divisions, a 5-class characterisation scale is used. Zero implies absence of, 1 equivalent to 25% while 4 equal 100%. Traces are indicated by the + sign. The use of symbols is another characteristic of the scheme.

In the Troels-Smith scheme there are 17 deposit elements, divided into five main groups classified as turfa, detritus, limus, argilla and grana. Long et al. (1999) shows some modifications of the scheme for describing coastal sediments. A peat comprising 100% fragments of stems and leaves of herbaceous plants is recorded as Dh4, while a peat with 50% roots and stumps of woody plants and trunks and twigs with 40% clay and 10% fine sand is recorded as Tl2 As2 Gmin1. The degree of humification for organic deposits is recorded as a superscript, also on a five point scale. Thus, referring to the last example but have a slightly humified peat with plant structure well preserved, is written as $Tl^{1}2$ As2 Gmin1. The nature of lithological contact between the upper and lower layer (limes superior) is also given by the 0-4 scales. In the field, sediment is described by filling a ready-made form of the observed sediment characteristics.

While using the scheme it is noted that there is some difficulty in differentiating between Limus detrituosus (Ld) and Substantia humosa (Sh) as both involved fine organics. Troels-Smith (1955) had also recognised the difficulty, instead recommended that the former deposit be also classified as Sh, which is also adopted in this study. The usage of Grana classification follows Aaby and Berglund (1986), where Grana minora (0.06-2.0 mm) and G. majora (2.0-60 mm) were proposed.

The usage of symbols for plotting the lithological description made Troels-Smith scheme useful for plotting graphical presentation. This is more so by the adoption of the scheme by Grimm (1991-1993) and Waller et al. (1995) in their respective TILIA and TSPP computer programmes, where both programmes are being widely used in Quaternary investigations.

4.4.3 Levelling

All the auger holes were levelled to the nearest benchmark (Fig. 4.8). Both in the west and east coasts, benchmarks are located within the boreholes transect lines. These had excluded the necessity of erecting temporary benchmark and further reduced the surveying error, since only a short distance survey was required. However, this is not so for the surface sampling sites. Since the main road generally neither crosses the present day swamps nor runs exactly along the present coasts, the nearest available benchmark is then surveyed to the particular contemporary sampling sites and a temporary benchmark was erected. The surface samples taken were then levelled to the erected benchmark. The benchmark values (altitude) are referred from the Malaysian Survey and Mapping Department, both in Kuala Lumpur and Kuantan. These benchmarks are related to the national height control datum based at Port Kelang.

The equipment used throughout the survey work is the Sokkia Dumpy Level. The distance between reading and staff points are always kept short, less than 100 m during the survey, so to reduce the error margins. Shennan (1982a) indicated an error of 0.02 m for levelling to the benchmark. The longest distance surveyed in the study is the transect at Meru, Kelang covering 4.5 km distance with altitude difference of 2.32 m between the lowest and highest points. Transects of the surface sampling sites are all very short; none exceed a distance of 1 km. At Jeram, Kelang the mangrove

Fig. 4.8 Levelling a borehole in Penor, Kuantan.

coasts sampling site showed an altitude difference of 2.96 m, from lowest sampled point to the land edge, over distance of 390 m.

4.5 Laboratory analyses

In the laboratory the contemporary and core samples were processed for microfossil analyses, which include pollen and diatoms. Samples were taken from the sediment cores within the stratigraphic contacts of the upper peaty and the lower clayey/silty layers. Sediment samples 0.2 cm thick are taken at about 2-3 cm intervals, above and below the contact zone. As for foraminifera analysis, only an assessment of their presence was undertaken, given the limited sample availability especially from the cores. Sediment samples were taken from core KEC13, below the regressive contact and scanned for foraminifera. Samples were also taken for radiocarbon dating.

4.5.1 Pollen analysis

Pollen analysis has been the principal technique in paleoecological studies (Birks and Birks, 1980). Its importance is due to the fact that pollen and spores are usually the most abundant fossils preserved in Quaternary sediments. The resistance to decay particularly in non-oxidising situations and their small size (commonly <60 μm) made it more likely to be preserved and encountered in the sedimentary environments involved. Also since pollen grains originate from plants that grew as the vegetation of the area, it provides a very useful means for reconstructing the past vegetation.

In this study pollen analysis is used to identify the sea level index points and indicative meanings of the fossil and present environments. Here, pollen implies both the pollen grains produced from both the gymnosperms and angiosperms and also applies to the spores of the pteridophytes when used within this context.

Pollen preparation follows the standard method (Faegri and Iversen, 1975). In the preparation about 0.5 ml of sediments were processed. The treatment that follows include removal of alkali soluble organic compounds (10% KOH), removal of coarse fragments (using 180 μm sieve), removal of siliceous material (HF treatment), removal of unaltered lignin and cellulose (acetolysis), staining (with safranin) and mounting (using silicone oil). Prior treatment with 10% HCl is occasionally done when the sample to be processed contains many shell fragments. In the entire sample preparation two *Lycopodium* tablets were added. The added spore tablets are meant for the calculation of pollen concentration (Stockmarr, 1971), should the need arise. Detail of the preparation procedure is as listed in Appendix 3.1. In each preparation it is normal to process eight samples in a single run, since the processing is limited by the centrifuge ability. When more than eight samples are simultaneously prepared the processing is carried out in batches of eight. Since pollen preparation involves the use of hazardous chemicals most of the processing is carried out in a fume cupboard. When in the laboratory, care should always be exercised, wearing of appropriate attire like eye protection, gloves and a laboratory coat are required.

In the analysis, pollen is identified using the Nikon YS2-H model microscope having 10x, 20x, 40x and 100x objectives. Generally 400x magnification is used for counting, while 1000x magnification with oil immersion for identifying difficult grains. Counting proceeds either in a horizontal or vertical traverse. For every sample a total of at least 200 grains (land pollen plus *Acrostichum aureum*), but excluding other fern spores were counted. In many samples counts had to be made from more than two slides, and in some cases up to five slides (Appendix 2). For samples with low pollen concentration it is often the case that the prepared residues were all used up and made into slides and the pollen counted. The slide is generally counted completely. But in some samples only half- or in few cases a quarter-slide only was traversed, especially in samples with abundant pollen grains.

The criteria most often used in identifying the pollen, apart from experience of the analyst, is the pollen morphology; which includes shape, size, aperture, sculpture and wall-structure. The identification of the pollen is grouped into two categories: the identified and the unidentified types. The identified pollen is assigned to the modern taxa. The unidentifieds are generally due to the concealment of the morphological features, which prevent them from being recognised. These may be due to various factors including broken, corroded, folded or hidden pollen. The unidentifieds also include the unknown pollen, which are not recognised even though they may be well preserved and the features obvious. Ferns and fungal spores are also counted and identified or described.

Modern reference material is consulted and compared during the identification process. The reference collection of the Quaternary Section of the Department of Mines and Geosciences Malaysia was used in this work. Other references like Thanikaimoni (1971), Huang (1972) and Traverse (1988) were also consulted. It is the practice to identify the pollen to its lowest rank, i.e. its species level. However, often this is difficult to accomplish because of the similarity in overall-look between the species. The pollen of *Rhizophora* and *Eugenia* are good examples, where they are represented by at least three species in the peninsula (Ng, 1978 and 1989). Thus most often identification is to the genus level, but sometimes the pollen was identified to family level and in cases to represent two families, since differentiating between the either families is not possible. Examples of the latter include Meliaceae/Sapotaceae and Amaranthaceae/Compositae.

Apart from the general observations in the field, pollen ecological affinity is mainly interpreted from botanical sources. The references consulted include Watson (1928), McCurrach (1960), Macnae (1968), Whitmore (1972a,b, 1973) and Ng (1978, 1989). Seven ecological subdivisions are recognised namely the mangrove, coast, back mangrove, coastal freshwater swamp, lowland swamp, lowland open and inland. Since this study is to reconstruct the ecological environments the pollen sum should include all the members of the population under study. Based on this principle all the land pollen (trees, herbs and shrubs), excluding the fern spores except *Acrostichum aureum*, is included in the pollen sum. The frequencies of each taxon are then calculated as percentages of the pollen sum. Fern spores were excluded from the pollen sum because they represent diverse ecological conditions.

The pollen analytical data is presented as a pollen diagram of frequencies versus altitude or depth, for all the fossil cores and the contemporary environments. Taxa with frequencies less than 2% are not shown in the diagrams. The fern and fungal spores profiles are also shown in the diagram, their frequencies calculated to the pollen sum. In the eight cores analysed eight pollen diagrams are produced (Figs. 6.8-6.15). For the six modern environments analysed only two main diagrams are created, each representing either the west or east coast contemporary sites (Figs. 6.1 & 6.2). In the west coasts two contemporary environments are combined while in the east coasts four present-day ecological sites are merged.

4.5.2 Diatom analysis

Diatoms have been widely used for paleoecological reconstructions (Battarbee, 1986). Palmer and Abbott (1986) indicate that diatoms are useful in sea level studies because the assemblages, which are often found in cores of fine-grained coastal sediments usually represent nearby microfloral populations and can accurately record the changing salinity of the local environment. In modern coastal environments the diatom communities often reflect the prevailing salinity of that habitat.

The diatom cell ranges in size from 5-2000 μm in length (Brasier, 1980). Most diatoms are autotrophic. Different species occupy benthic and planktonic niches in ponds, lakes, rivers, salt marshes, lagoons, seas and oceans while some even live in the soil or attached to trees. The benthic diatoms are very important in sea level studies. They are those that live attached to hard substrates or live in and on fine sediments such as silt and fine sand (Palmer and Abbott, 1986). Most of the benthic forms are elongated or feather shaped, forms known as Pennates. The free-floating planktic diatoms may also be transported by the seawater to the coastal sites and deposited. Most of the planktic diatoms are circular in outline, referred as the Centric forms.

In the laboratory, the procedure for diatom preparation is quite straightforward (Appendix 3.2). It is basically an oxidation process whereby all organics are dissolved and only siliceous material remains. About 0.5 ml of sediments are treated with hydrogen peroxide solution (20% H_2O_2) and later mounted on slides (using Naphrax). The diatom valves are identified under the microscope using 200x and 400x magnification. The identification of the diatom is referred to Werff and Huls (1958-1974) and Hendey (1964). Terminology follows Round et al. (1990) while salinity and life forms follow Denys (1991/2) and Vos and Wolf (1993). Other references like Round (1971), Werner (1977) and Hartley et al. (1996) are also consulted.

The diatoms can be classified in large ecological groups (Denys, 1991/2; Vos and Wolf, 1993). The main subdivision followed in this study is based on two ecological characteristics; salinity and life form (Vos and Wolf, 1988 and 1993). The salinity assemblages are grouped into polyhalobous (literally representing the marine forms, salinity >30‰), mesohalobous (brackish forms, salinity 0.2-30‰). Oligohalobian (salinity <0.2‰) forms reflect freshwater environments and may be differentiated into oligohalobous-halophile (salt-tolerant freshwater), oligohalobous-indifferent (freshwater) and halophobous (salt-hating freshwater). The life form assemblages are classified into episammic (immobile diatoms, which are firmly attached to sand grains), epipelic (mobile diatoms, which migrate actively through the sediment), epiphytic (typically associated with floating masses of aquatic plants or grow on the surfaces of various types of filamentous algae) planktonic (free-floating), tychoplanktonic (occur frequently in the water column but are also related to another benthic/epiphytic habitat) and aerophilic (those adapted to less frequent inundation).

It is the initial aim of this study that diatom analysis in combination with the palynological results would be used in interpreting the sea level index points. Thus in most samples fossil and contemporary, prepared for pollen analysis, the same sample levels are also processed for diatom investigations. However, except for the two cores KEC1 and KEC2, the fossil samples did not show an encouraging presence of diatoms (Appendix 2.2). Even so, in KEC1 from the six samples prepared only three samples showed the presence of diatoms, but in small to moderate amounts. In KEC2, although five out of six samples processed showed the presence of diatoms, abundant diatoms are only found in the lowest two samples, in the marine clay. Nonetheless, the surface samples reveal abundant diatoms, in which for every sample, a count of more than 250 diatom valves was made. The frequencies of each taxon are expressed as a percentage of total diatom valves (TDV) counted. Grouping into the main ecological categories was also attempted. The results are presented as diatom diagrams of frequency versus altitude, displaying both frequencies of the individual taxon and the ecological groupings, at various sampling levels (Figures 6.16-6.19). In all the diagrams, taxa occurring less than 2% TDV is not shown. The various environments of the surface samples are combined to form four diagrams (Figs. 6.4-6.7), two each representing the west (Kelang) and the east coast (Kuantan).

4.5.3 Foraminifera analysis

The presence of foraminifera in the samples was assessed from core KEC13, since adequate samples were available from the core. About 5 ml sediment was taken at various levels in the silty sequence below the regressive contact (Appendices 1.13 & 2.2). Each sample was placed in a beaker with water and weak dispersant solution (e.g. Calgon), stirred occasionally and left for 24 hours to disaggregate. Next, the samples were wet sieved between 63 and 500 μm. For peaty and surface samples, they could be sieved directly without being left overnight. Most foraminifera if present should be contained within the sieved fraction. The larger sieve was checked for large foraminifera before disposal.

The sieved fractions were examined under a binocular microscope in water, using 40-80x magnifications. A narrow tip brush was used to scrape through the sample looking for the foraminifera, taking portions of the sample at a time. In the three samples (KEC13) examined, foraminifera were present, however in low amounts (Appendix 2.2). Detailed foraminifera analysis was not carried out. Furthermore, due to sample constraints, emphasis was placed on the pollen and diatom techniques, which require much smaller samples compared to foraminifera.

4.5.4 AMS Radiocarbon dating

In this study, all the sea level index points identified were dated using AMS radiocarbon dating. Seven samples from the stratigraphic contacts were collected and AMS ^{14}C dated at the NERC Radiocarbon Laboratory at East Kilbride, Scotland.

The selection of samples for dating is based purely on the litho- and bio-stratigraphic criteria. Prior to selection of samples the lithology of the cores was noted and the lithostratigraphic transects drawn. Subsequently samples were collected from various levels at the stratigraphic contacts and pollen analytically studied. The pollen results indicate a change in the sedimentary environment at the contacts. This established the sea level index points whereupon sampling levels for dating are earmarked.

The main advantage of AMS ^{14}C method is that only small amount of sample is sufficient. The small amount of sample means that the indicative range of the sea level index point is appropriately reduced. In all the submitted samples, only 1-2 cm thickness is taken. Hedges (1991) indicated that samples as small as 100 μgm can be AMS radiocarbon dated. However caution needs to be exercised during sampling so as to prevent or minimise any potential source of contamination. The samples were carefully taken, scraping the sides while only the centre-part was sampled, placed in aluminium foil, labelled, wrapped, sealed and sent to the radiocarbon laboratory. Hedges (1991) and Pilcher (1991) noted that a small amount of sample tends to give lower precision (because fewer ^{14}C atoms can be detected) and any effect of laboratory contamination will be relatively larger, thereby making the dates less accurate (especially for older dates). Further, Wohlfarth et al. (1998) indicate that long term storage, of more than 6 months of wet samples, appears to have a significant effect on the radiocarbon age, which resulted in ages that were several hundred to several thousand radiocarbon years younger than expected, even when samples are kept cool. Nevertheless, in this study the samples submitted for dating has been kept for about 1.5 years (interval after collection and upon submission for dating) and stored at 4°C.

4.6 Data analyses

Lithologic data of the fossil cores were computed using TSPP computer programme, version 4.13, of Waller et al. (1995). The transects were then lithostratigraphically correlated. Data entry, calculation and creation of pollen and diatom diagrams, all used the Tilia computing programme version 2, b4 of Grimm (1991-1993), while the pollen and diatom diagrams utilised the Tilia Graph (Grimm, 1991-1993) and the Microsoft Power Point software. The radiocarbon dates were initially uncalibrated but later calibrated to calendar ages BP using CALIB Radiocarbon Calibration Program, HTML version 4.3 (http://calib.org/calib/), of Stuiver et al (2000).

CHAPTER 5

STUDY SITES

5.1 Introduction

The study area is subdivided into the fossil and contemporary sites. Two stratigraphic transects were investigated in both Kelang and Kuantan, while two contemporary environments were studied in Kelang and four in Kuantan. Mangroves dominate the coastal environments at each site, and following a review of vegetation dynamics and sedimentary processes in mangroves this is a brief account on the Quaternary geology and geomorphological aspects of each site.

5.2 Mangrove environments

Mangroves are trees or bushes growing in tropical regions along sheltered shores, estuaries, gulfs and lagoons (Macnae, 1968). They form dense vegetation thickets that colonise the upper tidal coastal zones and capable of tolerating fully saline conditions. The term mangrove has been used to describe both the individual species of the ecological group or the complete community or association. The term mangal has also been used to describe the latter.

Even though maximum development of mangroves is attained along the moist warm coastlines of the tropics, its distribution is also known as far north as Kyushu, in Japan and Bermuda, to as far south in South Africa, Victoria, in Australia and north New Zealand (Chapman, 1977; Woodroffe and Grindrod, 1991). Temperature has been suggested as the limiting factor of its geographical limit. Mangroves generally would not survive air temperatures below -4°C, even though sensitivity to temperature may vary between species.

5.2.1 Mangrove zonation

Within the mangroves, vegetation zonations are known and have been discussed by many including Watson (1928), Macnae (1968) and Tomlinson (1986). Watson (1928) presented a summary of the mangrove ecology of the Kelang-Langat delta (Fig. 5.1). He related the mangrove forest types to five classes (Class 1 to 5) on the supposed basis of height and frequency of tidal inundation. The zone inundated by all tides (Class 1) is generally devoid of vegetation, but in protected areas along the banks of streams *Rhizophora mucronata* is found. In the zone flooded by medium high tides (Class 2) the genus *Avicennia* and *Sonneratia* are found. The zones inundated by normal high tides (Class 3) are found most of the mangrove species, where *Rhizophora* predominates. Areas that are inundated by spring tides only (Class 4) are characterised predominantly by *Bruguiera*. Finally, the Class 5 zone, inundated only by exceptional tides (twice a month), are found *Bruguiera gymnorhiza*, generally with dense undergrowth of *Acrostichum aureum* ferns. Edaphic figs and climbers are common and sometimes form pure stands above the reaches of the highest tides. The Nipa palm (*Nypa fruticans*), Nibong palm (*Oncosperma tigillarium*) and various weeds and ferns may also be quite successful in this transitional zone between mangroves to the slightly inland freshwater swamps.

De Haan (1931, in Macnae, 1968) proposed an alternative scheme for the zonation of mangroves. Based on salinity of soil water and tidal flooding, he introduced two main divisions, each with subdivisions. Table 5.1 outline the divisions suggested.

Table 5.1. De Haan's (1931, in Macnae, 1968) subdivision of the mangroves.

Sub-zones	Description
Zone B	Fresh to brackish water zone with salinities between 0-10‰
B2	Areas seasonally flooded
B1	Areas more or less under the influence of tides
Zone A	Brackish to salt water zone with salinities at flood tide of between 10-30‰
A4	Areas flooded on a few days only, in each month
A3	Areas flooded $\leq$ 9x per month
A2	Areas flooded 10-19x per month
A1	Areas flooded 1 or 2x daily on each of 20 days per month

It is clear that the zones A1 to A4 of De Haan's are equivalent to the five classes of Watson's definition, but with some overlapping: A2 with Classes 2 and 3 and A3 with Classes 3 and 4.

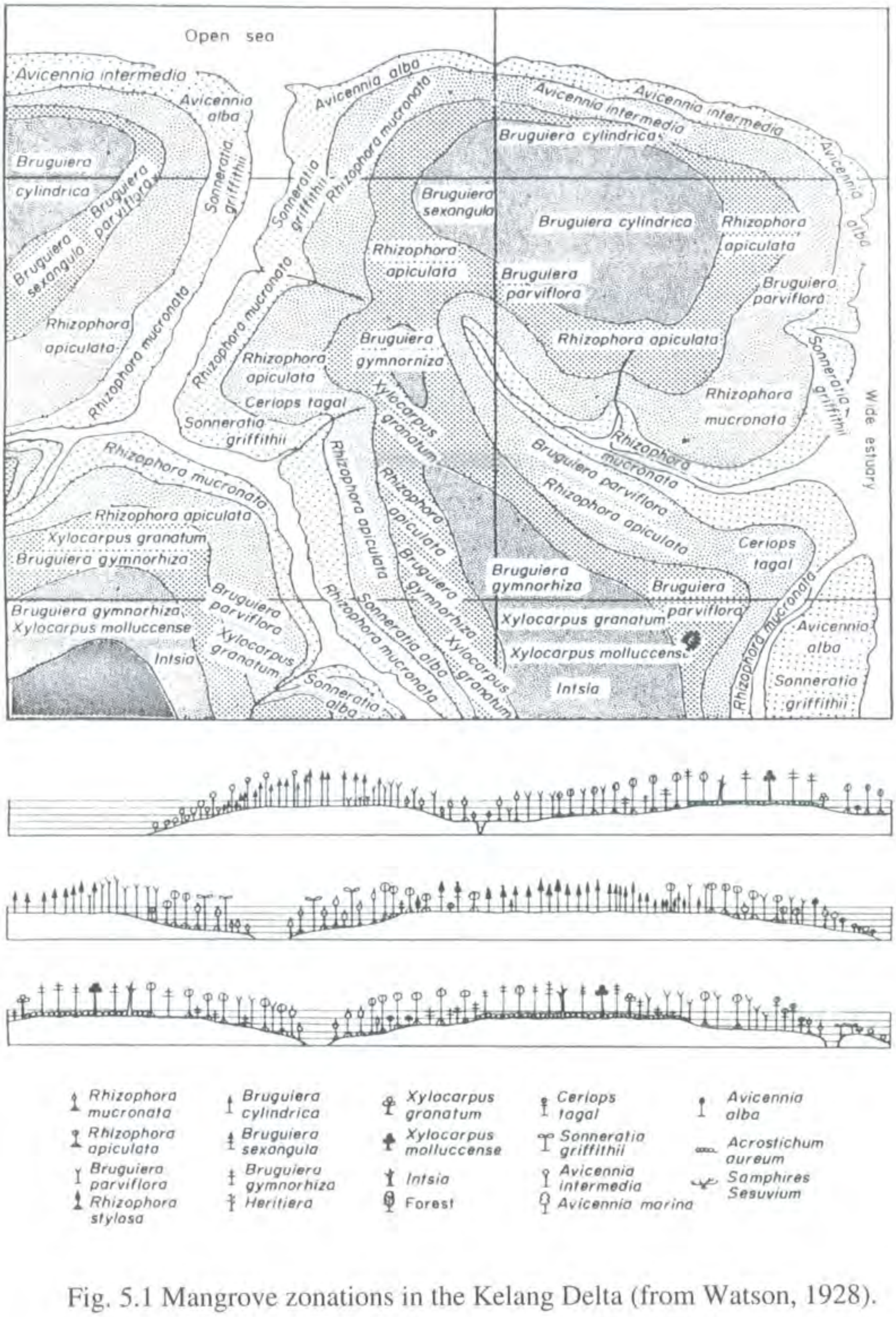


Fig. 5.1 Mangrove zonations in the Kelang Delta (from Watson, 1928).

Macnae (1968), following some earlier works, provided detail zonations of the mangroves based on the dominant vegetation. He summarised the mangrove swamps and forests of the Indo-West-Pacific regions into six zones; the landward fringe, zone of *Ceriops* thickets, zone of *Bruguiera* forests, zone of *Rhizophora* forests, seaward *Avicennia* zone and the *Sonneratia* zone. Fig. 5.2 shows Macnae's representative mangrove transect diagrams for the west coasts peninsular Malaysia. Table 5.2 summarises the scheme of Macnae's as compared to Watson's and De Haan's.

Table. 5.2. Zonations within a mangrove ecosystem (modified from Macnae, 1968).

Watson (1928)		De Haan (1931, in Macnae, 1968)		Macnae (1968)
5	Areas flooded by exceptional high tides	B	Fresh to brackish water. Salinity 0-10‰	Forests of the landward fringe
		B2	Areas seasonally flooded either by fresh or brackish water	
		B1	Areas more or less under the influence of tides	*Nypa* association
		A	Brackish to salt water. Salinity at high tide 10-30‰	
		A4	Areas flooded on only a few days in each month	*Barringtonia* association or
4	Areas flooded by spring tides only			Samphire association or *Xylocarpus granatum* or *Lumnitzera littorea* or *Bruguiera sexangula*
		A3	Areas flooded ≤ 9x per month	
3	Areas flooded by normal high tides			Zone of *Bruguiera* forests
		A2	Areas flooded 10-19x per month	Zone of *Rhizophora* forest
2	Areas flooded by 'medium high tides'			Zone of *Avicennia marina*
1	On land flooded at all tides	A1	Areas flooded once or twice daily on each of 20 days per month	Seaward fringe of *Sonneratia alba*, or *aptela* or *griffithii*

5.2.2 Environmental controls

The distribution and zonation of the mangroves have been attributed to several physical and biological factors (Macnae, 1968; Chapman, 1984; Boaden and Seed, 1985; Tomlinson, 1986; Woodroffe and Grindrod, 1991). These include climate, geomorphology, tidal range, salinity and human influence.

Climate plays a vital role in mangrove growth and development. Extensive mangrove swamps are generally associated with areas having average temperature

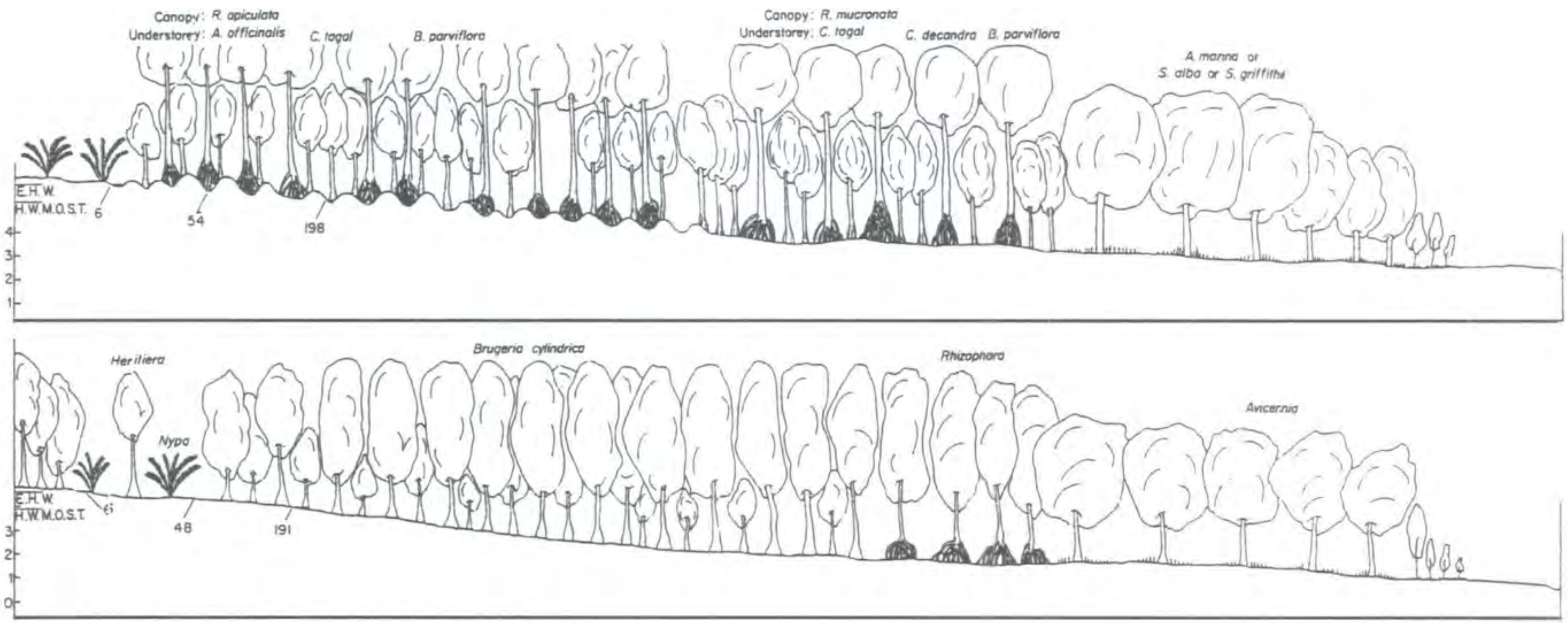


Fig. 5.2 Two mangrove transect diagrams from the west coasts of peninsular Malaysia (modified from Macnae, 1968).

above 20°C and seasonal range of around 10°C. Mangroves are most luxuriant in areas of high precipitation, where complete mangrove succession is commonly only found in areas with an evenly spread annual rainfall of above 2000 mm.

Mangroves are often associated with muddy soils, even though they can be found on sand, peat and coral rocks. The former is commonly found in deltas, estuaries, lagoons and bays. Generally, these locations are also sheltered from strong waves and tidal currents.

Tidal range controls the vertical zonation of some mangrove species. The frequency and duration of tidal inundation seems to be especially important for the establishment and subsequent survival of the mangrove propagules. In coasts with large tidal ranges and associated gentle slopes, extensive mangrove areas may develop and a wide range of communities are often present.

Mangrove species vary in their tolerance to salinity. This adaptation varies in accordance with the appropriate species occupying the respective zone of the environmental gradient. Hypersaline conditions have been known to cause stunting.

Human influence usually induces intense stresses on mangroves than other natural causes. Economically mangroves are important, the timber is used in construction, charcoal and for its tannin properties. Excessive logging can result in changes in species composition. Mangroves also benefit the fishing industry. It is known that many fish and prawn species rely on the mangroves for spawning and hatching. Mangroves act as sediment traps. Drainage schemes, coastal structures, land reclamation, extensive use of defoliants (e.g. during the Vietnam War) and developing and conversion of mangrove lands for other uses are among the examples that induce negative effects to the mangroves and associated ecosystems.

5.3 Kelang and its vicinity

The study area is situated within the Kelang lowland coastal plain (Fig. 5.3 & 5.4). Kelang is a major town in the state of Selangor, on the west coast of peninsular Malaysia. It is situated at the foot of the Late Paleozoic hills (Yin, 1988). Some distance to the east the hills merge with the peninsula's Main Range, which is made up of the Mesozoic granites. To the northwest, west and south of the town stretches the west coast Quaternary coastal lowlands. Along the coast, strips of mangrove vegetation generally less than 500 m wide align the shore. The mangrove forms the

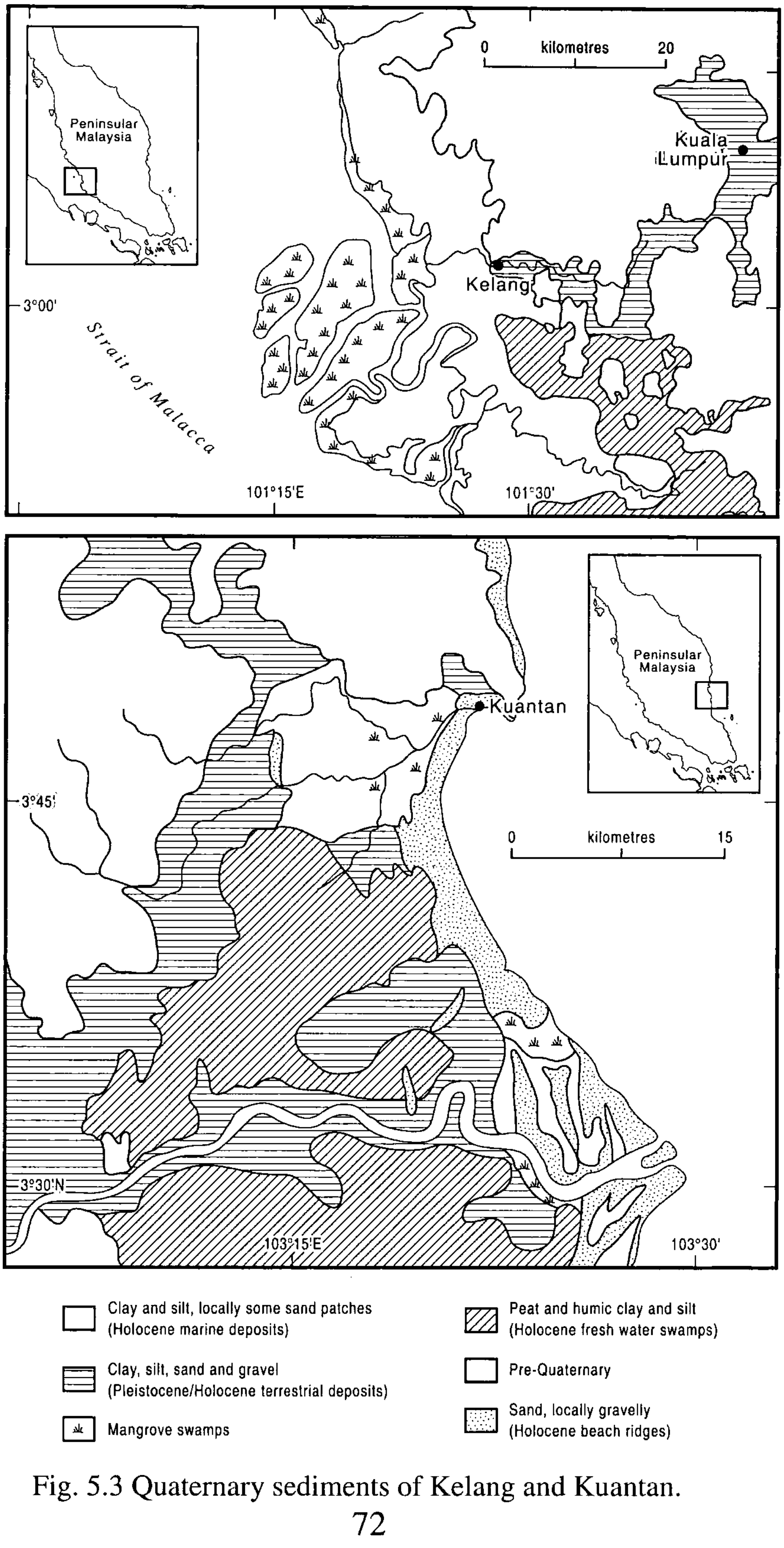


Fig. 5.3 Quaternary sediments of Kelang and Kuantan.

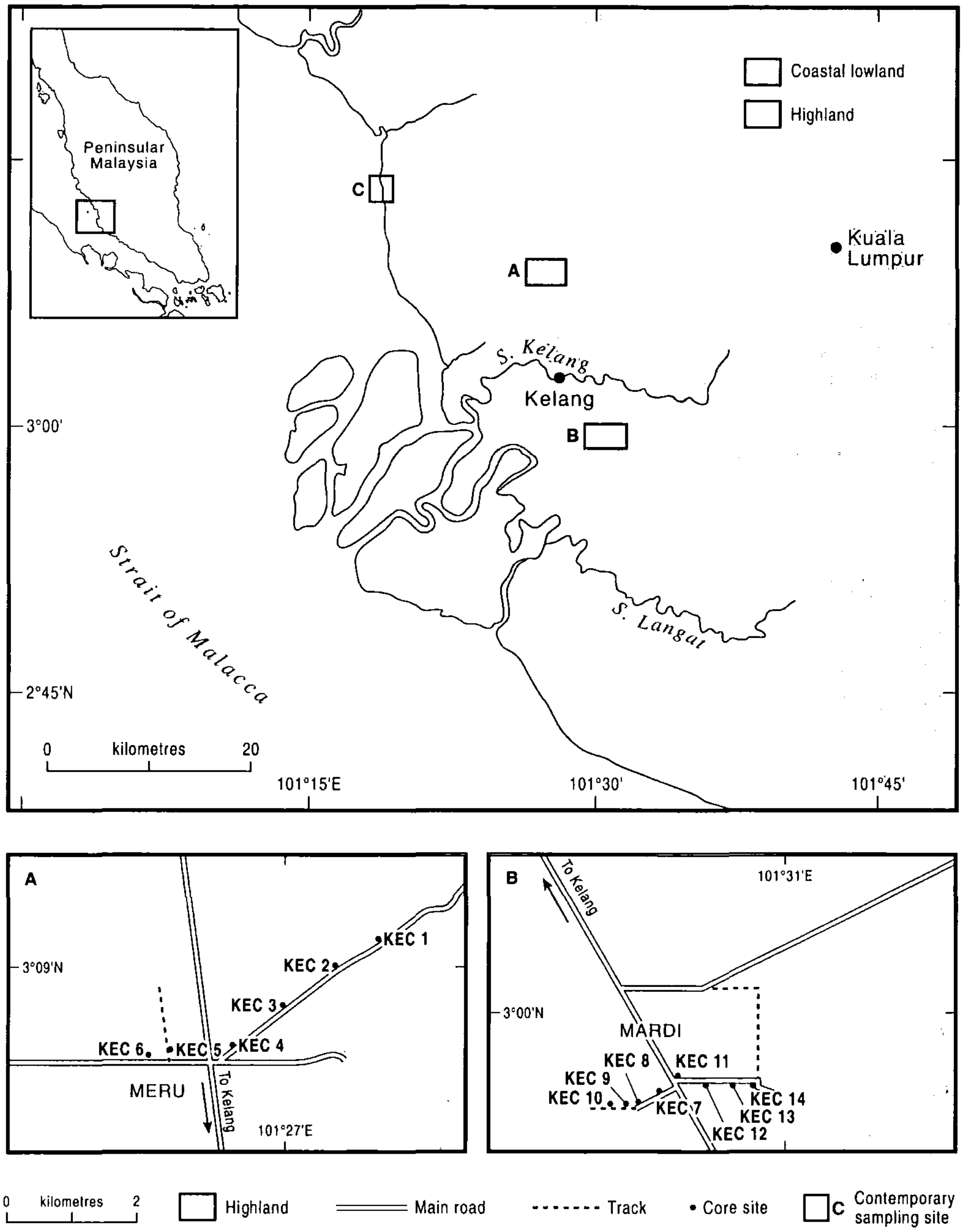


Fig. 5.4 Location of the study sites in Kelang.

barrier between the land and sea, a common feature along the peninsula west coast shoreline (Kamaludin, 1993). About 9 km southwest of Kelang at the estuary of Sungai Kelang (sungai is river in Malay) is Port Kelang, the principal shipping harbour of peninsular Malaysia, developed on mangrove-reclaimed shore.

The area experiences mean annual rainfall ranging from 2000 to 2800 mm. Two main rivers, the Sungai Kelang and Sungai Langat flow through the lowland's rather flat plain. Coleman et al. (1970) indicated that the coastal plain is a product of Quaternary progradation resulting from sediment being introduced to the coast by many small rivers and deposited in the comparatively calm waters of the Strait of Malacca. The net result is a coastal plain, which is essentially the compound delta of many small streams of which the main ones are the Sungai Kelang and Sungai Langat. The Sungai Kelang form the main river that flows through Kuala Lumpur (Malaysia's capital city), and Kelang town in its lower course. The drainage basin of the Sungai Kelang is approx. 1000 sq. km (Coleman et al., 1970). At the mouth of both the Sungai Kelang and Sungai Langat there are five mangrove colonised deltaic front islands.

The factors important in shaping the Kelang-Langat deltaic coasts are the tides and tidal currents (Coleman et al., 1970). The Kelang-Langat delta is described as a tide dominated delta. In the Malacca Strait the dominant direction of the tidal current is to the northwest. The tide levels of the Port Kelang Tide gauge is as shown in Figure 5.5 (Anon, 1996). The tides are semidiurnal and have a mean spring range of approx. 4.3 m. Following Davies (1964), the Kelang-Langat delta is classified as macro tidal.

5.3.1 Contemporary Sites

The study of contemporary environments is important in sea level investigation since it provides information on the altitudinal relationships between the biological assemblages and the tide levels and the application of such relationships in interpreting the fossil sequences. The selected contemporary sites from the west coasts are at Jeram and Pantai Remis, located about 30 km and 26 km northwest of Kelang town respectively. At the Jeram site surface sediment samples are collected from the mangrove coasts while at Pantai Remis from the back mangrove *Nypa* vegetation (Fig. 5.6). The samples from both ecological sites

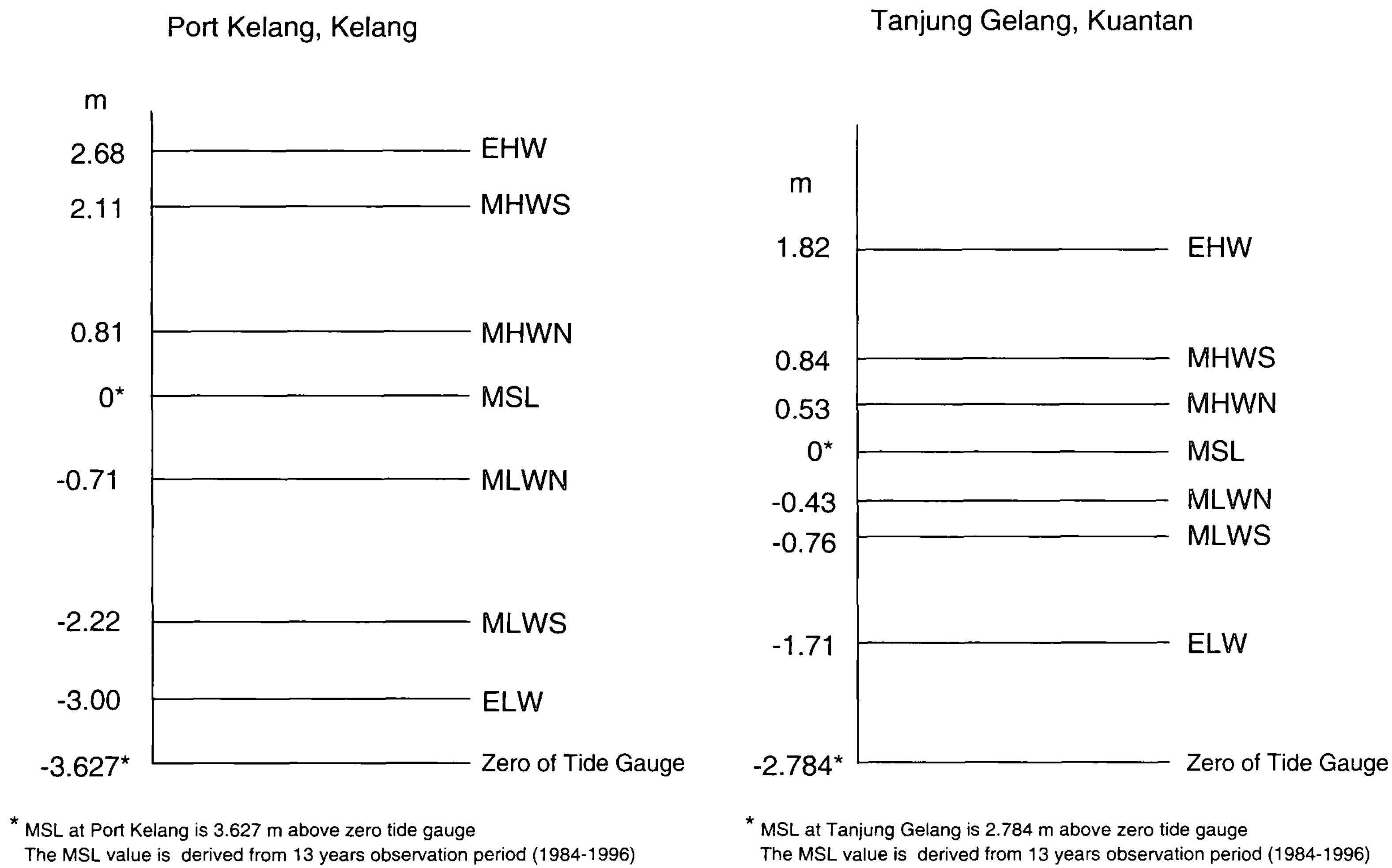


Fig. 5.5 Tidal levels at Kelang and Kuantan referred in the study.

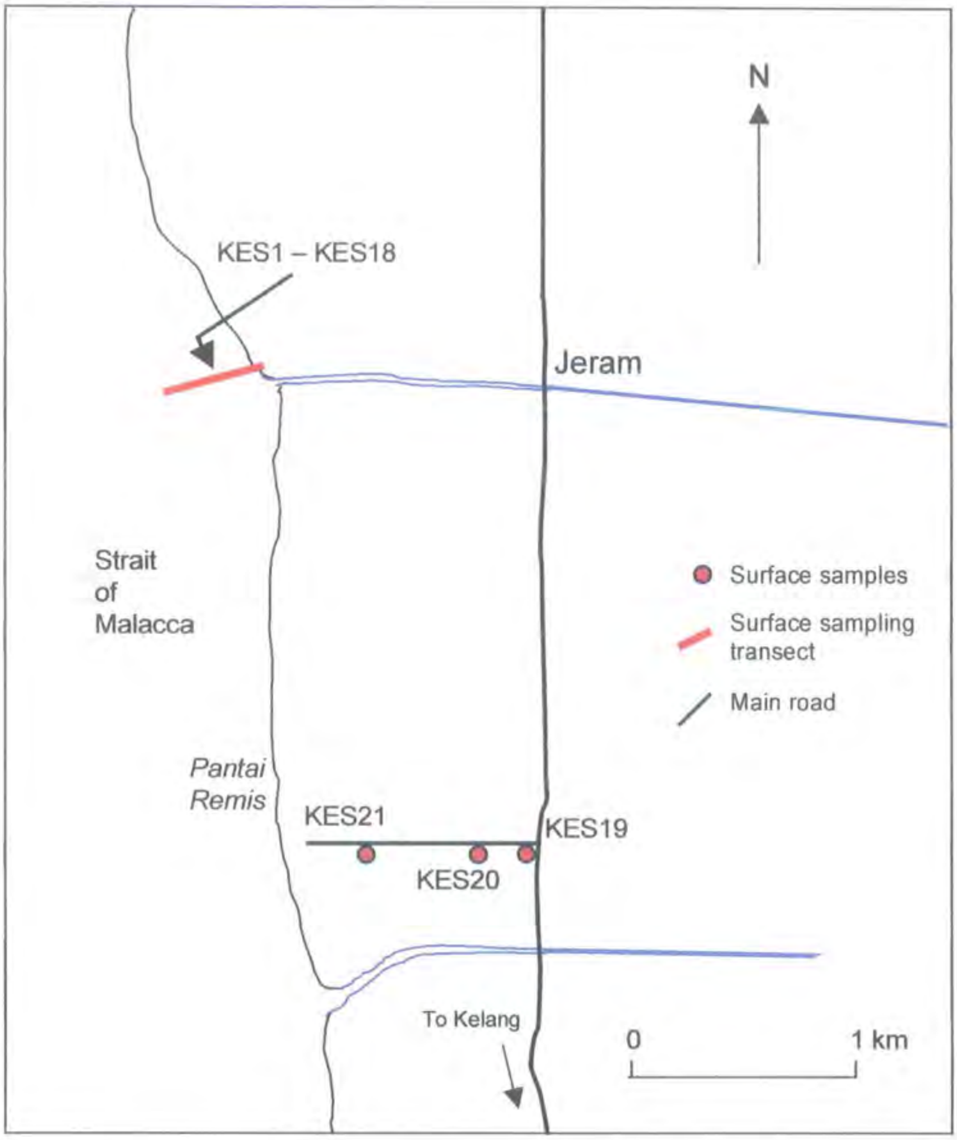


Fig. 5.6 Surface sample locations near Jeram and Pantai Remis, Kelang.

represent the tidal and upper intertidal sedimentation zones. The summary description of the samples is presented in Table 5.3. The frequency of daily inundation is extracted from the 1996 tidal records published by the Department of Survey and Mapping, Malaysia (Anon, 1996). In this study it is assumed that the present environments and tidal levels are similar to the paleo situations, when sedimentation of the coastal plain at Meru and Mardi had accumulated.

Table 5.3. Description of the surface samples from Kelang and relation of sampling altitude to frequency of tidal inundation.

Sample no.	Altitude (cm) to MSL	Frequency (%) of daily tidal inundation	Kelang surface samples and tidal reference
	268.3	<0.2	EHW
KES18	218.1	1	Embankment-side
	211.3	1.5	MHWS
KES21	192.7	3-4	*Nypa* vegetation
KES17	180.1	5-6	Embankment-foot
KES19	175.9	6-7	*Nypa* vegetation
KES16	144.9	12-14	Mangrove tidal swamp
KES20	143.9	12-14	*Nypa* vegetation
KES14-KES15	85.2 to 92.6	25-28	Mangrove tidal swamp
	81.3	30	MHWN
KES11-KES13	54.2 to 74.0	32-39	Mangrove tidal swamp
KES6-KES10	5 to 44.2	40-50	Unvegetated tidal flat
	0	51	MSL
KES1-KES5	-21.0 to -1.4	51-60	Unvegetated tidal flat

Table 5.3 and Fig. 5.5 present the actual relation between the tides and the intertidal mangrove. The levels experiencing more than 40% daily tidal inundation appeared not to be vegetated. Up the tidal frame, with frequency of daily inundation less than 39%, the interval is swamped by mangrove vegetation. The corresponding level of mangrove initiation is between MSL to the MHWN, but closer the latter. The back mangrove vegetation, represented by the *Nypa* vegetation, is slightly higher up the tidal level. This starts from about 14% daily inundation level, about midway between MHWN-MHWS.

5.3.1.1 Mangrove coast, Jeram

Along Jeram coast, mangrove vegetation mainly represented by young *Rhizophora*, occupies the upper tidal flat, inundated by most high tides. However, it is barren of any vegetation cover from the middle to lower flats. The tidal flat shows a fairly gentle gradient. The Jeram coast is protected by man-made concrete and rubble embankment (Fig. 5.7). A stream debouches to the sea about 100 m south of the sampling transect.

Figures 5.6 and 5.8 show the Jeram transect and sampling locations. The transect runs approx. ENE-WSW, perpendicular to the coastline. Sampling was carried out during low tide on 26 July 1998 (Tide Tables, 1998). A total of 18 surface sediment samples labelled KES1 to KES18 were sampled. The sampling transect covers a total distance of about 390 m of the intertidal zone, with altitude levels spanning from –0.210 to 2.181 m MSL (KES1 to KES18). Ten samples KES1 to KES10 were collected from the barren tidal flats, six samples KES11 to KES16 from the mangrove vegetated zone and two samples KES17 and KES18 at the foot and side of the embankment respectively (Table 5.3). The sediments are generally silty and clayey, but predominantly shelly in 4 samples (KES14, KES15, KES17 and KES18). The sediment was sampled by scraping about 10 x 10 cm and 1 cm deep of the surface layer. The sampling method was also applied for all other contemporary sites. Subsequent to each and every sample collected, the sampling location was consecutively levelled.

Mangrove has been a source of economy for the local population for quite some time and is also known to have contributed much to the fishing industries. The mangrove trees provide poles and are important source of firewood and charcoal. It is an invaluable habitat for fish, crustaceans and molluscs, which depend on the mangroves for propagation, nursery and growth. It is also involved in stabilising soil movements and checking erosion in the riparian and littoral zones. Due to its importance exploitation of the mangroves is being controlled by the states. In Perak, cutting of the mature trees is restricted to a 40 years cycle and large areas have been protected as forest reserves. Nonetheless, due to the pressure of development and expanding population large areas of the coastal mangroves have been cleared and converted for other uses like agriculture, aquaculture and the building of new townships.

Fig. 5.7 Jeram coast during high tide (looking north). Note the young mangrove trees and the rubble embankment.

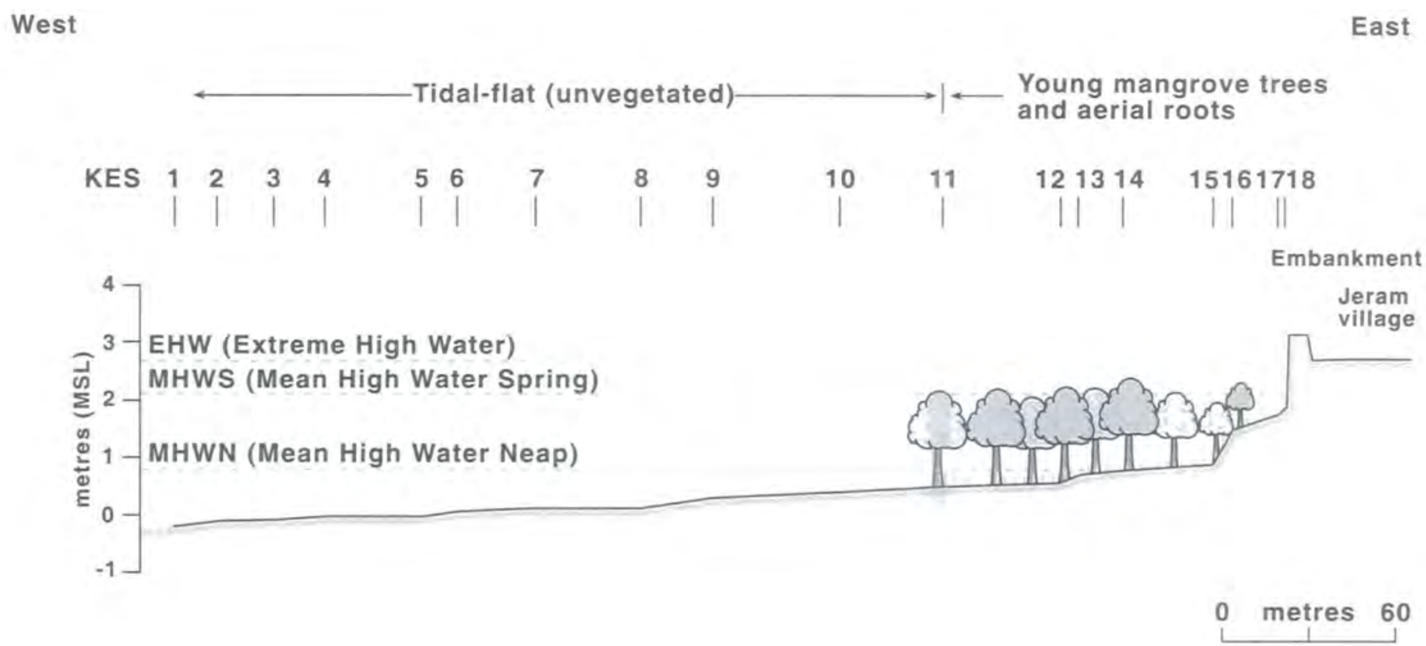


Fig. 5.8 Surface sampling across the tidal flat and mangrove vegetation at Jeram, Kelang.

5.3.1.2 *Nypa* vegetation, Pantai Remis

At Pantai Remis, *Nypa* vegetation occurs within a narrow belt about 300 m to 1 km inland from the shoreline (about MHW mark). The *Nypa* palms form clumps and clusters in association with other palms and vegetation types, the *Nypa* colonising the low lying surfaces with the latter more prominent on the higher and raised ground. The *Nypa* palms within the sampling vicinity are tall, probably about 10 m, and are considered mature. The stems are dark brown. Young *Nypa* shrubs, common in a thriving colony were not observed at the site. This is probably due to the minimal tidal effect experienced at the site. As indicated in Fig. 5.9, the area is inundated only during the spring tides. Even so tidal variations at the site is quite restricted and somewhat obstructed due to the silted channels.

Three contemporary samples, KES19, KES20 and KES21, were collected from the rather dry swamp surface. The sampling transect is east-west, KES19 the most inland site while KES21 the seaward location, distance between them about 660 m apart. The altitudes of the samples are 1.439, 1.759 and 1.927 m MSL (Table 5.3). The samples are of very organic silt.

McCurrach (1960) noted that *Nypa* only thrives when its base is at least partially submerged in brackish water. *Nypa* has been a source of roofing material, cigarette paper, sugar, vinegar and alcohol. Whitmore (1973) reported that in Sabah (East Malaysia), the vehicles of the British North Borneo Company had been running on alcohol made from the local *Nypa* swamps until the Second World War.

5.3.2 Fossil Sites

The fossil sites are located at Meru and Mardi (Fig. 5.4). The former is a small village town about 10 km north of the Kelang town, while the latter is 8 km south, near an agricultural research site called Mardi. Both the sites form the area inland most locations of the west coasts lowland coastal plains. They are each located on either side of the east-west flowing Sungai Kelang.

Bosch (1988) delineated the surficial sediments of the Kelang coastal plain into mainly the Holocene marine and paludal (swamp) deposits. The marine deposits are made up of clay and silt, and constitute large sections of the coastal plain. The

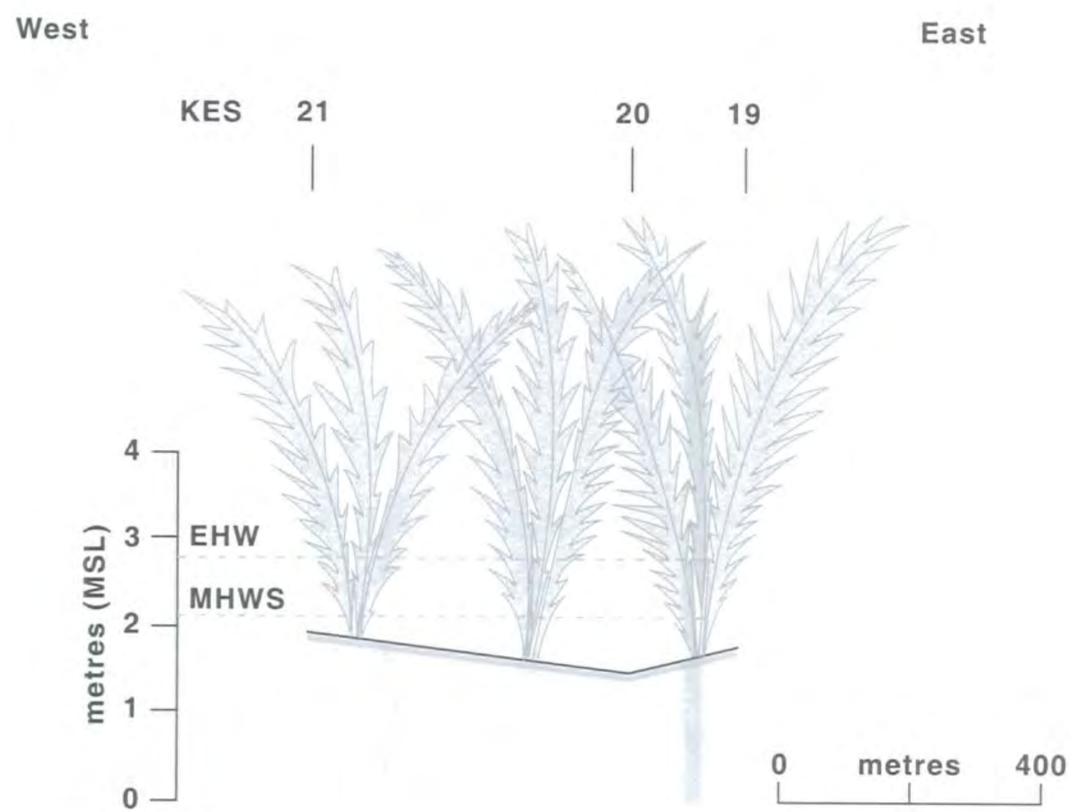


Fig. 5.9 Surface sampling points in *Nypa* vegetation, Pantai Remis, Kelang.

paludal deposit, comprising peat and humic clay, occupies the inland plain and generally overlies the marine clay. Bosch (1988) reported a date of 7200±160 BP from the base of a 1.25 m thick peat layer overlying marine clay, for a sample collected near Mardi.

5.3.2.1 Meru Stratigraphic Transect

Six boreholes, KEC6, KEC5, KEC4, KEC3, KEC2 and KEC1 were cored in Meru, running approx. southwest northeast, following the main road (Fig. 5.10). The cores are quite widely spaced. The total distance of the transect (between KEC6 and KEC1) is 4.05 km, while spacing between the boreholes ranges from 350 m to 1 km. The depth of coring is variable, ranging from 5.5 m in KEC1 to 15 m for KEC6. The borehole surface altitudes show a slight height increase inland, from 3.085 m in KEC6 to 5.404 m MSL in KEC1.

Three lithostratigraphic sequences could basically be delineated from the Meru transect. This is shown in all the boreholes except KEC6, where only two lithological sequences are indicated. The lowermost sequence of KEC1 to KEC3 is made up of silty sand, and in KEC4 and KEC5 of reddish brown and yellow/orange-mottled clay. The mottled clay is firm to stiff. In most of the boreholes that encountered the mottled clay layer, penetration gets very difficult and further coring is normally impossible. In the overlying layer, grey to greenish grey marine clayey silt predominates in all the boreholes, ranging in thickness from about 3.5 m in KEC1 to more than 14 m in KEC6. The top most layers is made up of woody brownish black to reddish black peaty silt to peat, varying in thickness from 21 cm in KEC6 to 1.1 m in KEC1. In KEC4 the peat layer is absent due to disturbance.

Sampling levels were determined after comparing the lithological descriptions of all the cores. Samples were taken from intervals that showed significant lithological change, from both the upper peat and the lower marine sequences. In the transect, KEC1 and KEC2 were selected and sampled, the former from 90 to 140 cm while the latter from 0 to 150 cm depths. The contacts between the upper peat and lower clayey silt are classified as conspicuus to diffusus (Troel Smith, 1955), at about 110 and 71 cm depths in KEC1 and KEC2 respectively.

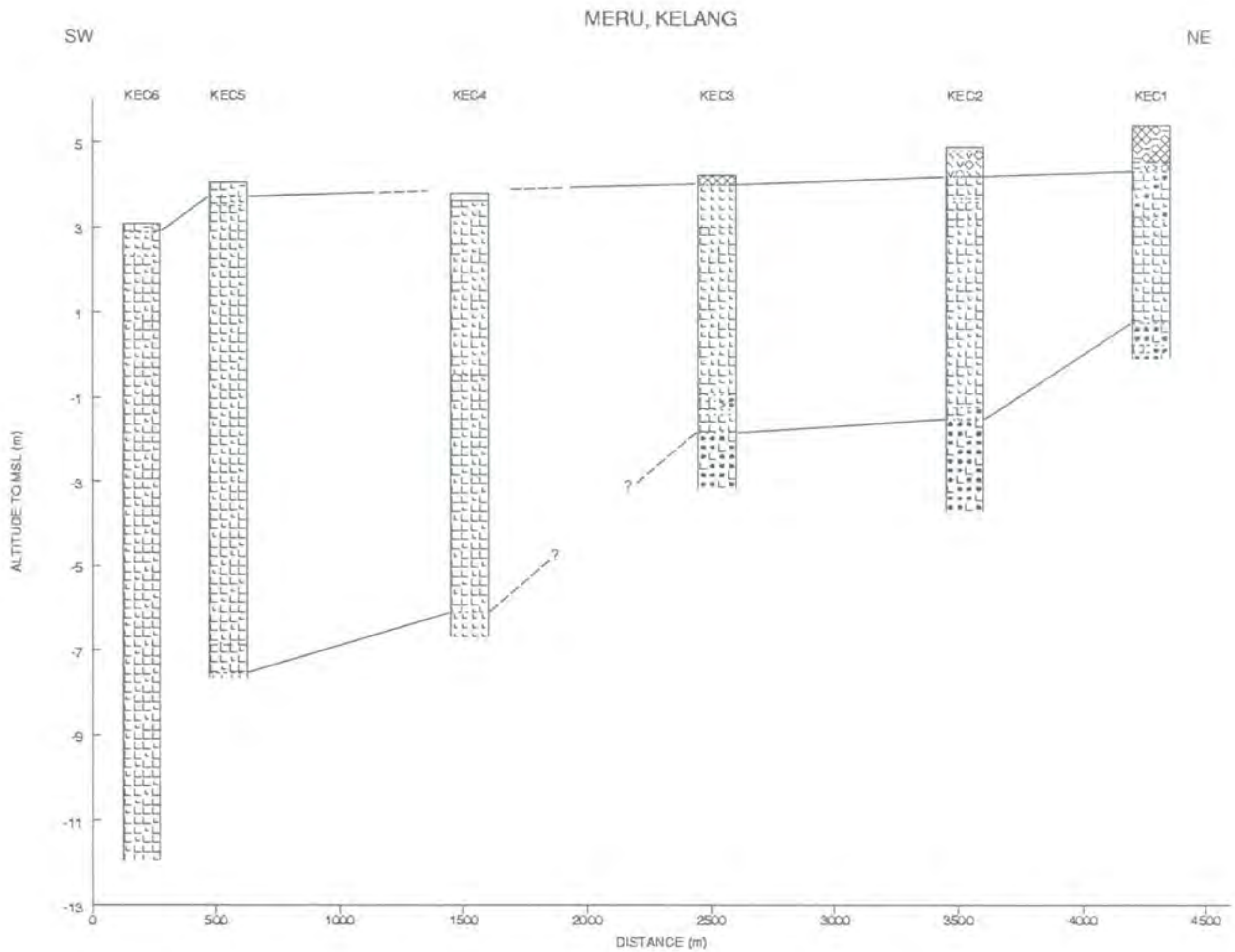


Fig. 5.10 Stratigraphic transect in Meru, Kelang.

5.3.2.2 Mardi Stratigraphic Transect

Eight boreholes, KEC10, KEC9, KEC8, KEC7, KEC11, KEC12, KEC13 and KEC14, oriented approx. west east were cored at Mardi (Fig. 5.11). Borehole intervals in the transect range from 200 to 400 m, are closer spaced compared to that in Meru. The depth of penetration of the boreholes ranges from about 5.5 m in KEC13 to 12.9 m in KEC8. The ground elevation shows variation in altitude across the transect, from 7.097 m in KEC10, 4.928 m in KEC11 and 6.001 m MSL in KEC14. Basically the ground surface is slightly higher compared to the Meru transect.

In the Mardi transect, two and three lithostratigraphic sequences could be delineated, shown from respective profiles KEC10, KEC9, KEC7, KEC11 and KEC8, KEC12, KEC13, KEC14. In KEC8, KEC13 and KEC14 the lowermost sequence starts with the bright yellowish brown and dark red very firm to stiff mottled clay, while in KEC12 with the silty sand layer. The yellowish grey, grey to greenish grey marine clayey silt sequence is predominant in all the boreholes ranging from about 3 m in KEC13 to 11.2 m in KEC11. The uppermost sequence is represented by the reddish brown to reddish black woody peat layer, ranging in thickness from about 7 cm in KEC11 to 2.4 m in KEC10. The KEC11 site shows major disturbance of the topsoil from agriculture, whereas the locality of KEC10 is on a recently cleared site and least disturbed.

In the transect, four stratigraphic contacts of KEC9, KEC8, KEC7 and KEC13 were selected for sampling. As in Meru, they represent regressive overlaps, the respective contacts are at approx. 191, 176, 71 and 96 cm depths, the boundary being conspicuus to diffusus (Troel Smith, 1955). The respective sampling levels of the cores are at depths of 170-220, 160-260 and 50-100 cm while for KEC13 the whole core was sampled.

5.4 Kuantan and its vicinity

Kuantan, the capital of the state of Pahang, is the major town in the central peninsular Malaysia east coasts. It is situated on a quite narrow coastal lowland at the northern bank of the Sungai Kuantan estuary (Fig. 5.3). Triassic granite hills

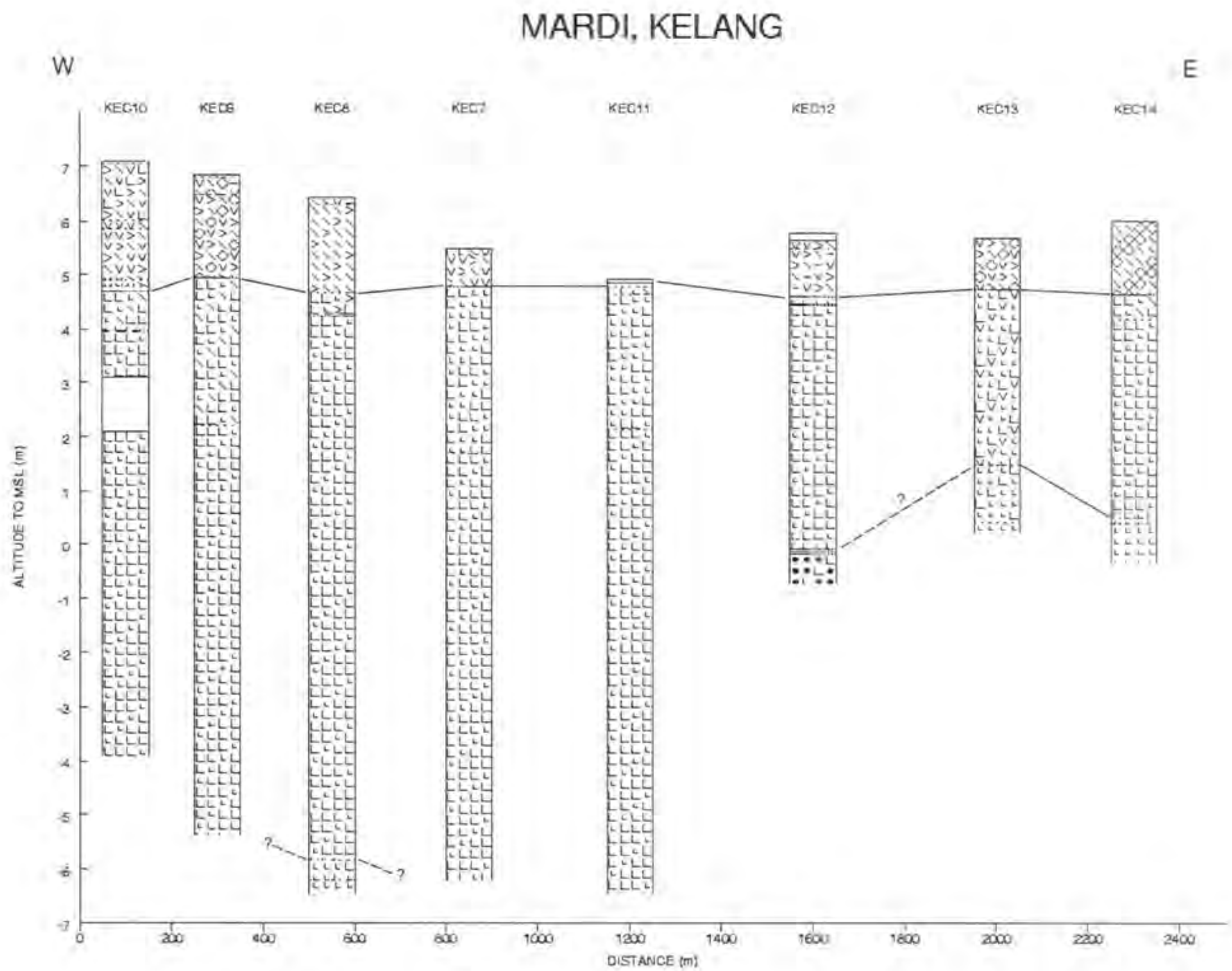


Fig. 5.11 Stratigraphic transect in Mardi, Kelang.

(Gobbett and Hutchison, 1973) surround the town in the north, east and west. Basalts dated 1.6 m.a. (Bignell and Snelling, 1977), occur slightly north of the granites. To the south and southeast across Sungai Kuantan, Quaternary coastal lowlands occupy extensive areas, up to more than 35 km wide from the foothills in the west to the coasts in the east. The lowlands are slightly undulating to rather flat and are generally made up of terrestrial, swamp and beach deposits. Terrestrial sediments are mainly found between the hilly terrain and swampy plains and are made up of various combinations of clay, silt, sand and gravel. The Holocene swamp deposits (Bosch, 1988), consist of both freshwater and brackish-water peat, the former occupying large areas of the coastal plain whereas the latter is more common near streams and rivers. Holocene beach ridges, ranging from few hundred metres to more than 2 km wide, align the coastline. The sand that made up the beach ridge deposits is generally fine to coarse grained and well sorted (Nossin, 1965). This beach sediment also underlies the Kuantan town. Mangrove vegetation is absent along the coasts, only thrives in estuaries and along rivers, streams and swamps, inland of the beach ridges. About 30 km south of Kuantan, the east-flowing Sungai Pahang (longest river in the peninsula) dissected the Pahang coastal plain, before debouches to the South China Sea.

The Pahang coastal plain is rather sparsely populated when compared with most areas of the west coast coastal plain. The population is mainly concentrated within the beach ridges and coastal areas, while the coastal swamps which made up more than 70% of the Pahang coastal lowlands are mainly covered by swamp forests and uninhabited. The swampy nature makes it difficult to access. The vegetation comprises mainly the freshwater swamp types with palms and ferns also observed thriving (Fig. 5.12).

The study areas are situated in the coastal plain between Kuantan town and the Sungai Pahang (Fig. 5.13). The average annual rainfall throughout the area is more than 2500 mm. Most rainfall is recorded between October and March, during the northeast monsoon. Along the coasts, the beach sediment transport by littoral drift is predominantly south-southeast wards (Raj, 1982). Tidal levels in the study area are referred from Tanjung Gelang, about 25 km northeast of Kuantan (Fig. 5.5). The tides are mainly of a semidiurnal frequency and the spring tidal range is approx. 1.6 m (Anon, 1996).

Fig. 5.12 Freshwater swamp south of Kuantan. Note the waterlogged condition. The trees in the background were burnt during a dry spell, few months before this picture was taken.

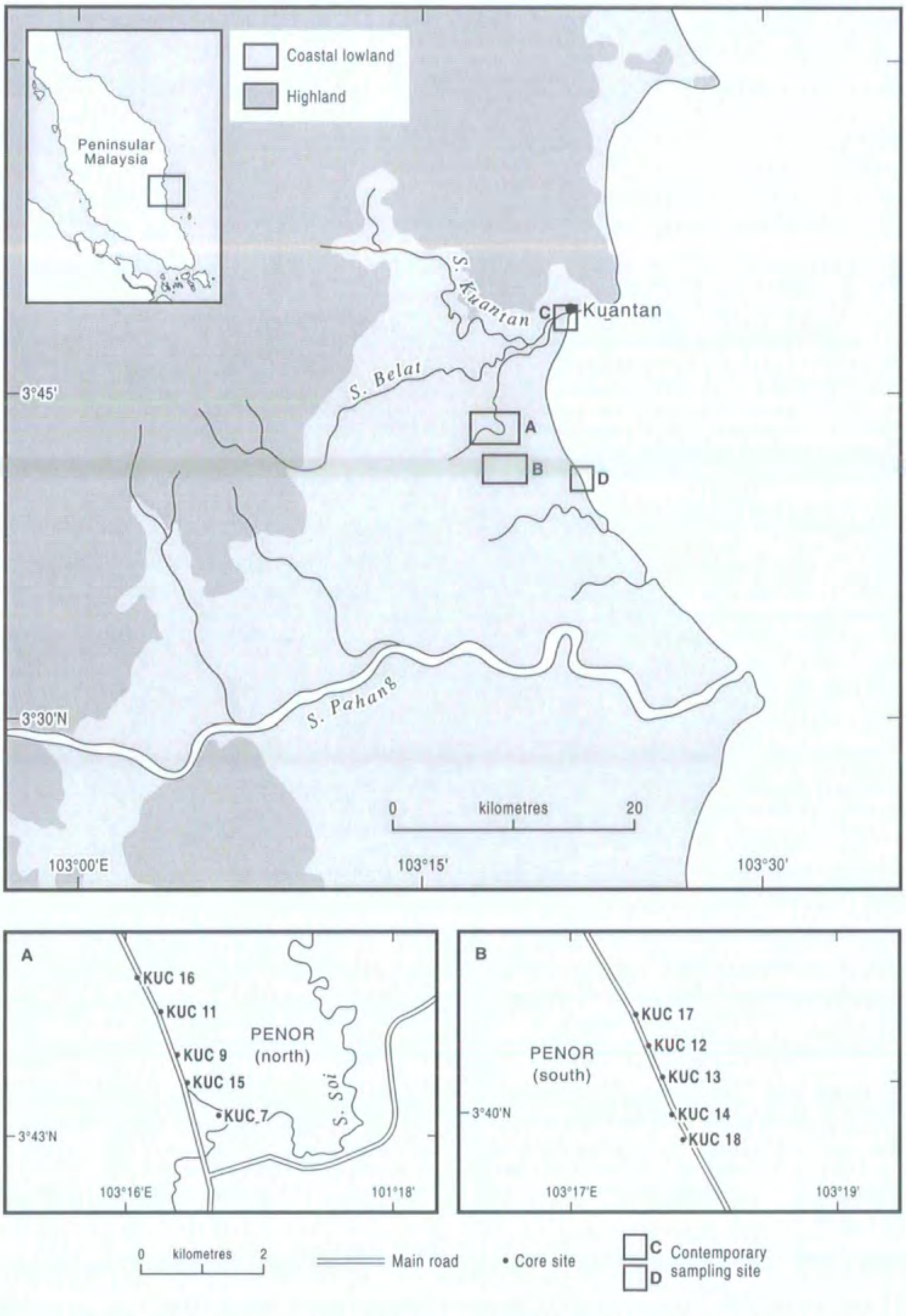


Fig. 5.13 Location of the study sites in Kuantan.

5.4.1 Contemporary Sites

Four contemporary sites are investigated in the east coasts area (Figs. 5.14 and 5.15). They are considered important ecological sites in the study since they represent different altitudinal levels of the tidal environments. The biological information they provide is vital in interpreting the paleo sea level index points. The selected sites represent the respective tidal and upper tidal zones of the mangrove and *Nypa* swamp, the upper-most tidal zone of the *Acrostichum aureum* vegetation and the supratidal coastal *Pandanus* swamp (Figs. 5.16-5.18). The description of the surface samples is summarised in Table 5.2. The frequency of inundation is extracted from the 1996 tidal records (Anon, 1996).

Three of the contemporary environments are situated near Kuantan on the opposite side of the river. The mangrove sampling site is located about 1 km from the Sungai Kuantan river mouth, on the mangrove vegetated south bank estuary, near the bridge-end of the Kuantan Bridge (a newly completed bridge across Sungai Kuantan connecting Kuantan and Tanjung Lumpur in the south). The *Acrostichum aureum* vegetation and the *Nypa* swamp samples sites are respectively located about 50 m and 600 m from the Kuantan Bridge bridge-end, the former on the west side and the latter on the east side of the main road (Fig. 5.14). Meanwhile the *Pandanus* swamp site is situated at 19 km milestone mark, south of Kuantan and about 400 m from the coast (Fig. 5.15).

The mangrove vegetation in Kuantan starts from the intertidal zone experiencing less than 40% daily inundation (Table 5.4, Fig. 5.5). This is rather similar to the observation in Kelang of <39% daily inundation. Also, the altitude of mangrove initiation level is noted comparable, about 28 cm below MHWN in Kuantan and 27 cm below MHWN in Kelang. The mangrove transect in Kuantan, in contrast to Kelang, is continuous until its inland vegetation edge. The back mangrove vegetation, represented by the *Nypa* swamp, thrives from a level experiencing less than 16% daily tidal inundation, which correspondingly starts from about slightly above the midway of MHWN-MHWS tidal level. The back mangrove *Acrostichum aureum* vegetation is observed to start near the top-most level of the intertidal zone, affected only by <1% daily tidal inundation.

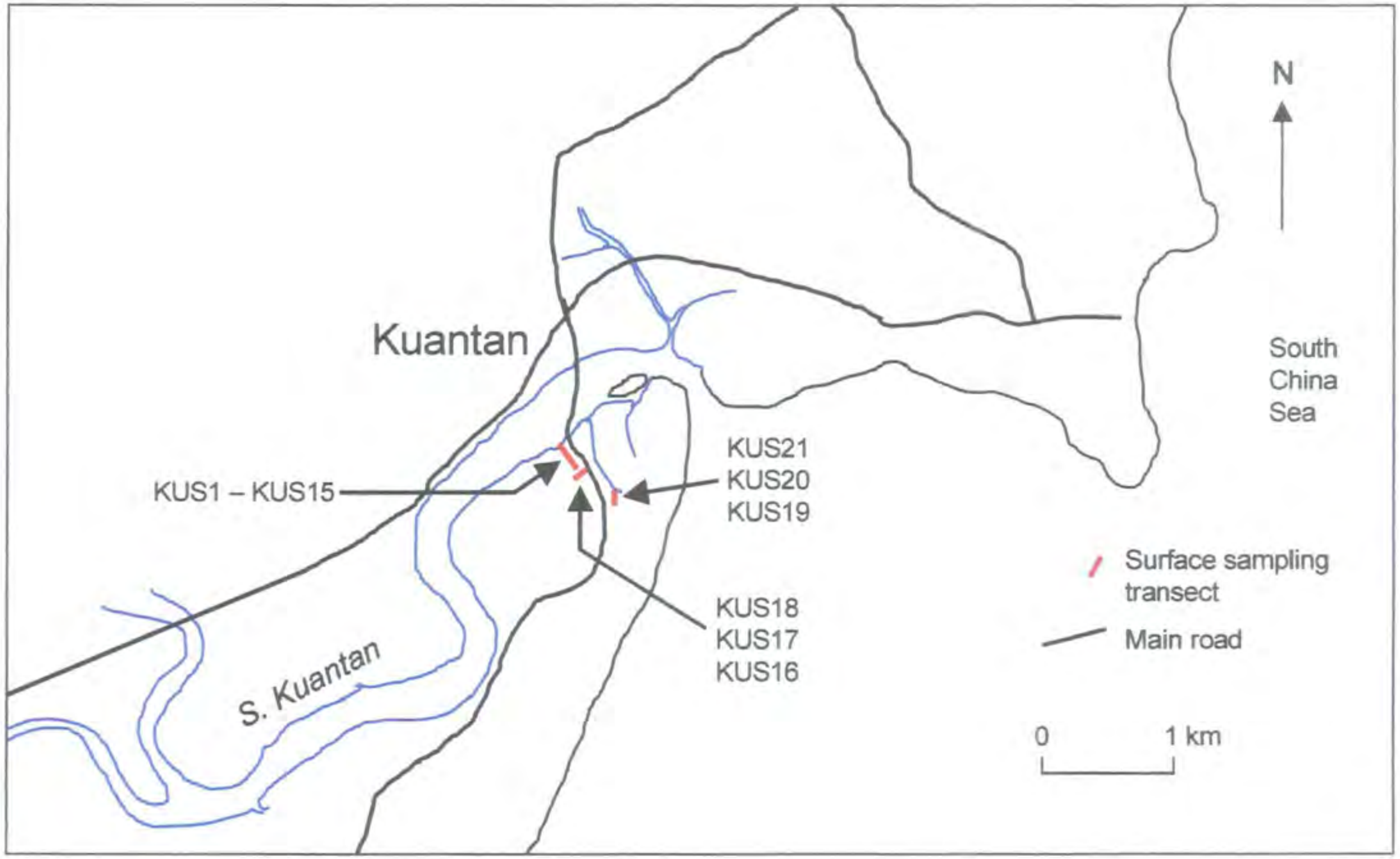


Fig. 5.14 Surface sampling locations in Kuantan

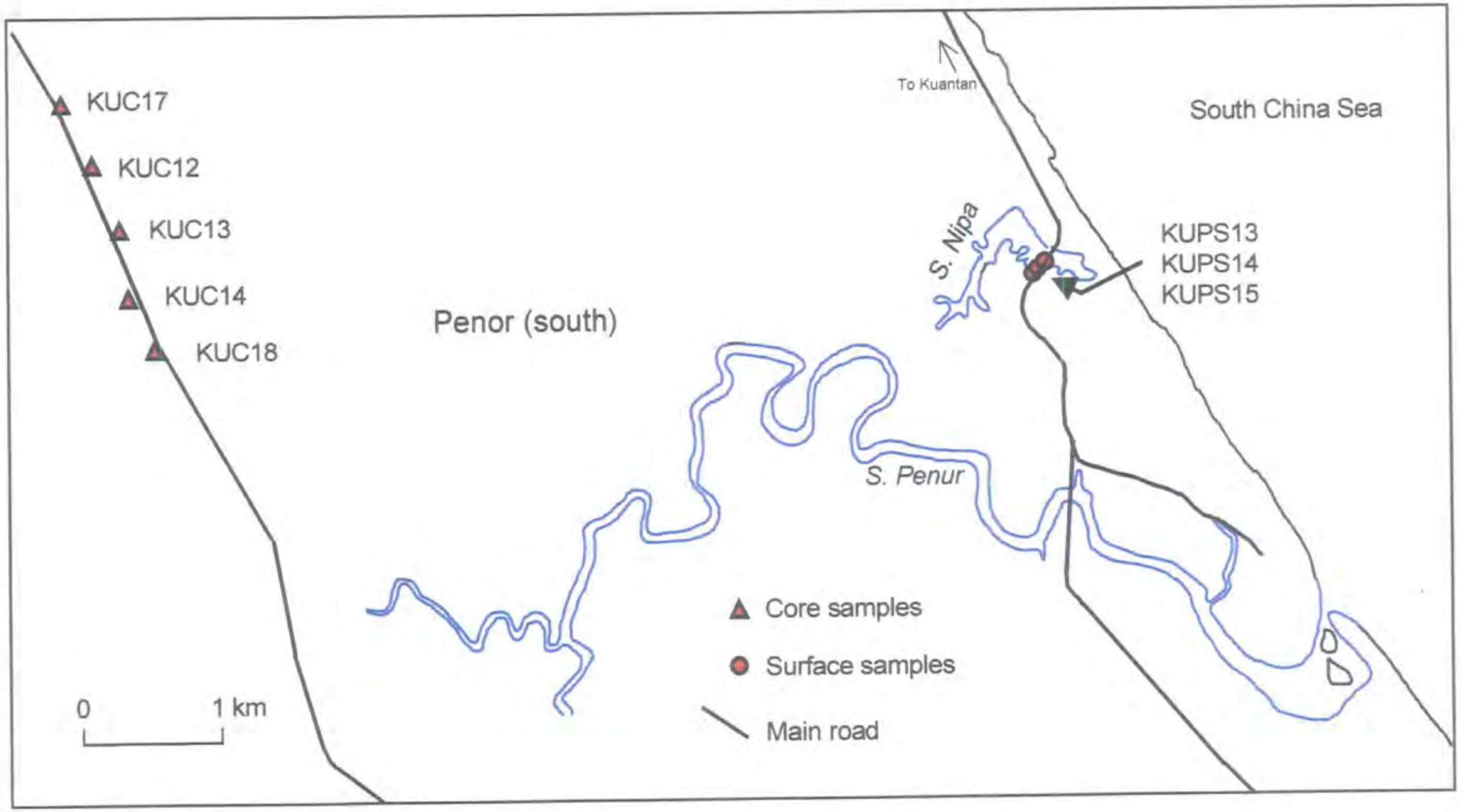


Fig. 5.15 Penor (south) sampling locations. Note the meandering S. Penur, which formerly debouched to the South China Sea through S. Nipa.

Fig. 5.16 Levelling and sampling across mangrove swamp, south bank of Kuantan river estuary. Note the straight line cut through the mangrove vegetation.

Fig. 5.17 Nipa (*Nypa fruticans*) swamp during spring tide near Kuantan.

Fig. 5.18 Pandan (*Pandanus*) swamp at Kampung Sepat, Penor (south), Kuantan.

5.4.1.1 Mangrove estuary, Kuantan

In the area, unlike that in the west coast, mangroves are limited to the riverbanks and estuaries. Even so, the mangroves only thrive well on the accreting banks of the river and are absent on the eroding sides. These reflect the nature of mangroves, which only swamp tidal shores with low current or wave activities. At the sampling site (Fig. 5.16), mangrove swamp forms a belt about 500 m wide and 1.8 km long. As shown in the transect (Fig. 5.19), pneumatophores are a prominent feature of the ground surface within the mangrove vegetation.

Table 5.4. Description of the surface samples from Kuantan and relation of sampling altitude to frequency of daily tidal inundation.

Sample No.	Altitude (cm) to MSL	Frequency (%) of daily inundation	Kuantan surface samples and tidal reference
KUPS13-KUPS15	356.6 to 375.6	Supratidal zone	Coastal *Pandanus* swamp
	181.6	No record	EHW
KUS16-KUS17	177.7 to 179.9	No record	End of *Acrostichum aureum* vegetation
KUS18	146.5	0.3-0.7	Start of *Acrostichum aureum* vegetation
KUS15	133.4	~1	Mangrove inland edge
KUS19-KUS20	109.8-110.0	4-5	*Nypa* tidal swamp
	83.6	10	MHWS
KUS21	70.9	14-16	*Nypa* tidal swamp
KUS12-KUS14	92.0 to 111.1	4-9	Mangrove tidal swamp
KUS7-KUS11	50.5 to 86.2	9-21	Mangrove tidal swamp
	42.6	25	MHWN
KUS5-KUS6	14.7 to 31.4	31-40	Young mangrove trees
	0	49	MSL
KUS2-KUS4	-38 to –5.0	51-75	Unvegetated tidal estuary slope
KUS1	-62.0	84-86	Unvegetated tidal estuary slope

15 surface samples, KUS1 to KUS15, were collected from the mangrove vegetated Sungai Kuantan estuary. Sampling was carried out during the predicted lowest tide of the month on 11 July 1998 (Tide Tables, 1998). The transect is oriented approx. NNW-SSE from the tidal riverbank landward and span about 125 m distance. The respective surface elevation ranges from –0.620 m in KUS1 to 1.334 m MSL in KUS15 (Table 5.4). The samples are generally clayey and silty. The collection of the three lowest samples (KUS1-3) was an experience and quite a task, due to the gradient of the slope and the nature of sediment. Not only was walking

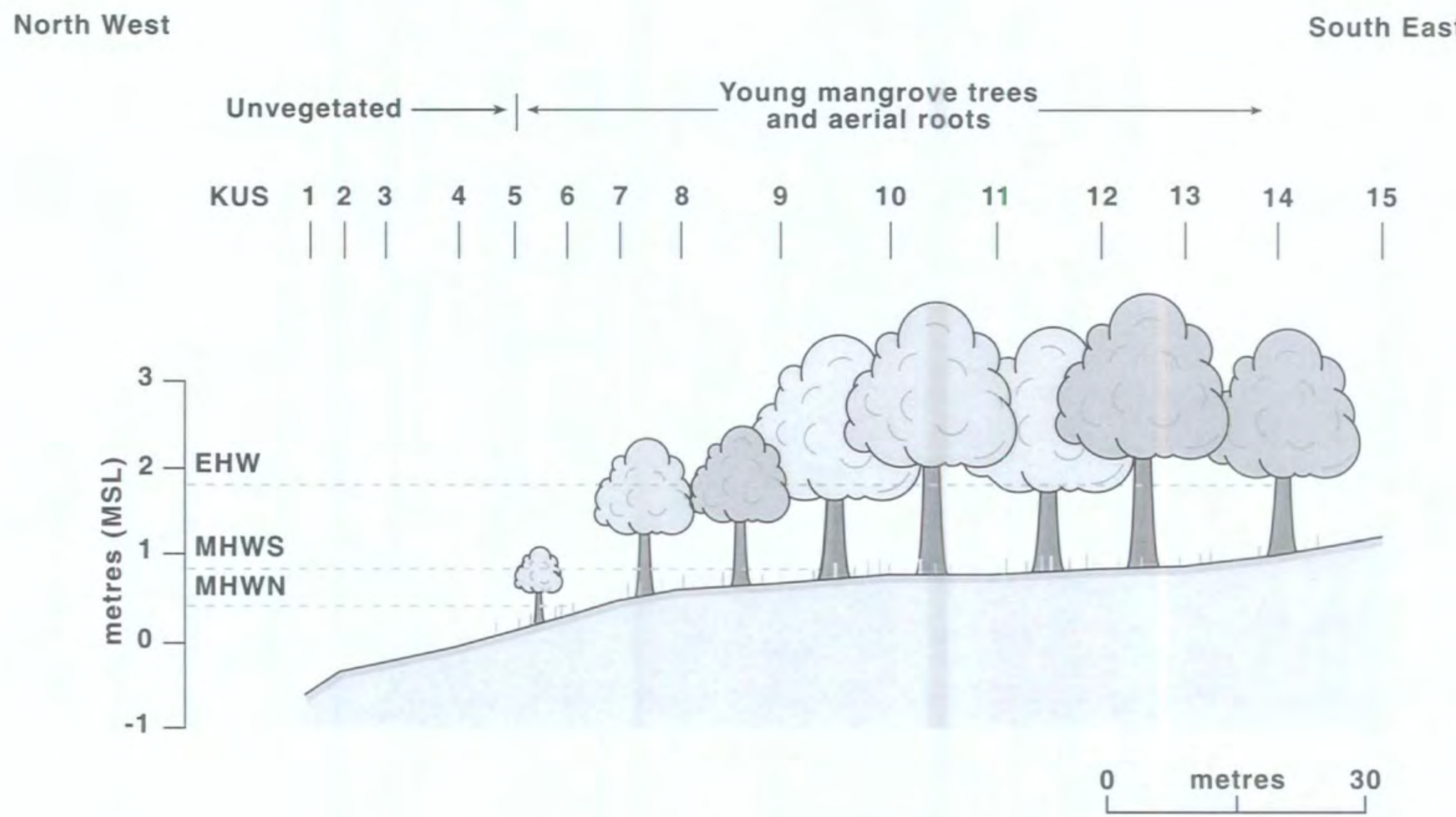


Fig. 5.19 Surface sampling across south bank of Kuantan River estuary.

made difficult by the soft and sloppy nature of the marine clay, it also literally sucks away the 'Wellington' from under the feet.

5.4.1.2 *Nypa* swamp, Kuantan

The *Nypa* vegetation at the site is thriving well and forms a large colony behind the mangroves, occupying a zone about 250 m wide inland of the mangrove (Fig. 5.17). Young *Nypa* plants litter the swamp close to the mangrove while mature palms densely vegetate the landward edge. Tidal influence is clearly observed at the site, since during the sampling period the area was experiencing monthly extreme tides. Figure 5.20 shows the transect and the tidal levels prevalent within the vicinity.

Three surface samples KUS21, KUS20 and KUS19 were collected from the site (Table 5.4). The samples respective reduced levels are 0.709, 1.098 and 1.100 m MSL. The sediments are quite organic and silty.

5.4.1.3 *Acrostichum aureum* and Grasses vegetation

Acrostichum aureum ferns and grasses cover the open and flat area, about 50 m from the Kuantan Bridge south bridge-end. As indicated in the transect (Fig. 5.21), pneumatophores are noted protruding from the ground surface at the lower end that is influenced by the extreme high tide level. These aerial roots are common in the mangrove plant community (Watson, 1928). *Acrostichum aureum* ferns solely occupy the ground surface around the EHW level, while grasses start appearing at the landward edge of the narrow *Acrostichum aureum* zone.

Three contemporary samples KUS18, KUS17 and KUS16 were collected (Table 5.4). Their ground surface altitudes are 1.465, 1.777 and 1.799 m MSL respectively. The sediment samples are sandy and silty. It is noted that during the sampling trip high tide was receding from the site, the highest tide mark nearly reaches the KUS16 sample level.

5.4.1.4 Coastal *Pandanus* swamp

Exquisite coastal *Pandanus* vegetation, rather uncommon in the west coast, thrives abundantly in a swamp near Kampong Sepat (Fig. 5.18). The *Pandanus*

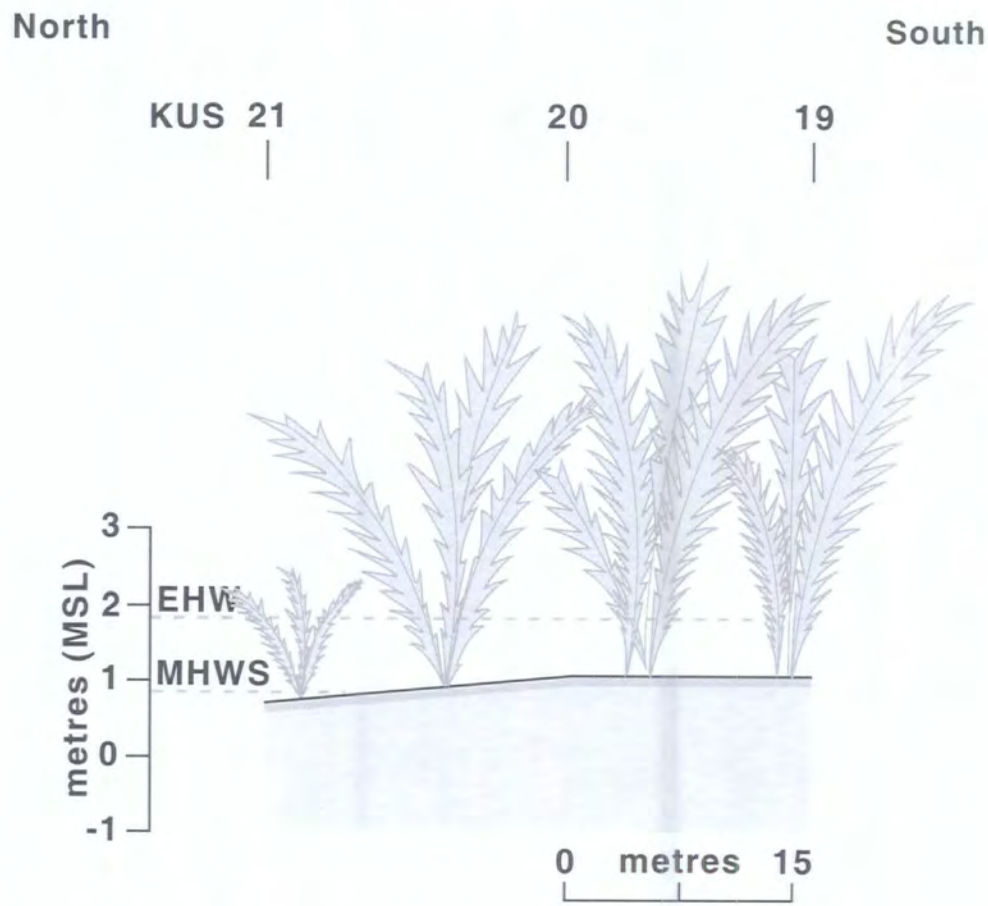


Fig. 5.20 Surface sampling in *Nypa* swamp, Tanjung Lumpur, Kuantan.

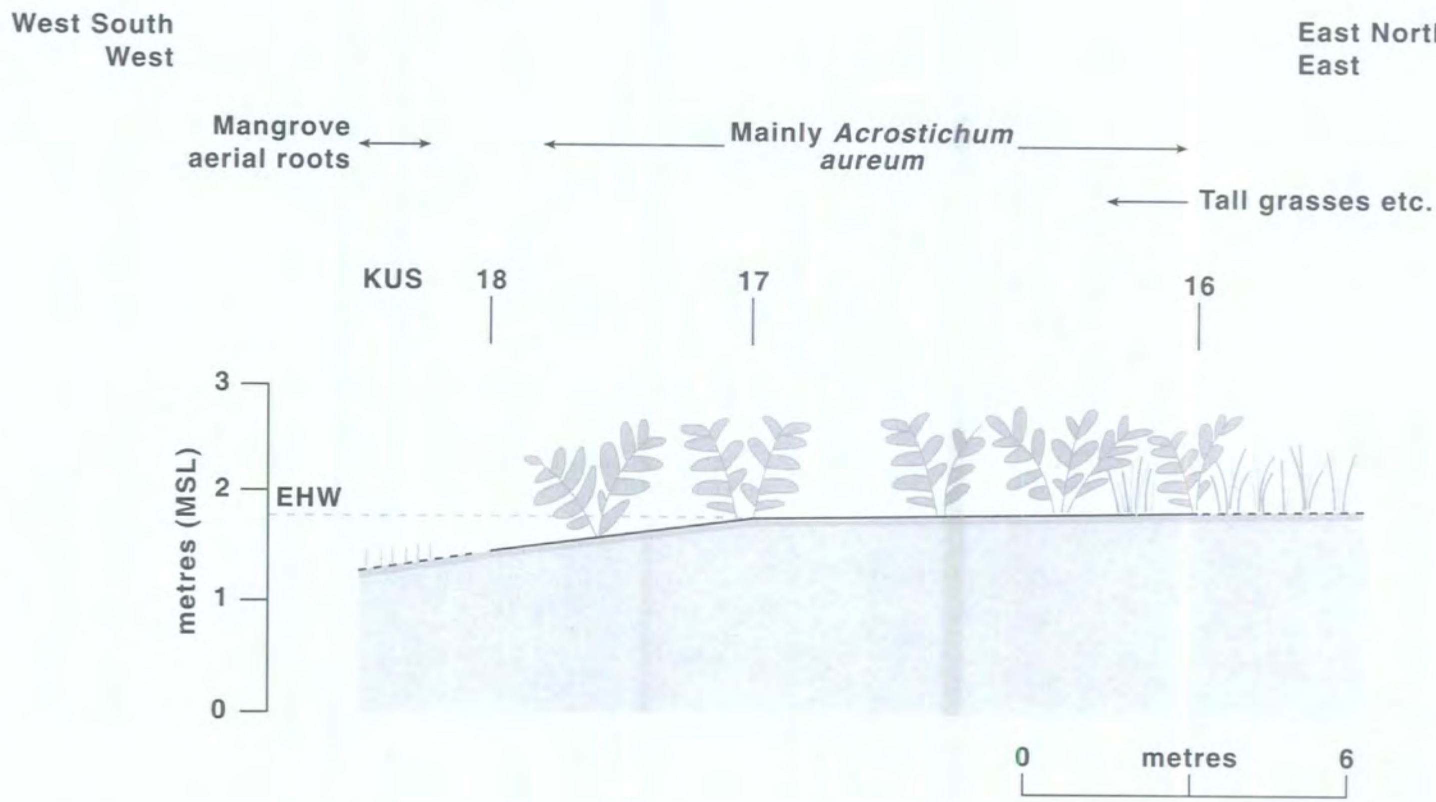


Fig. 5.21 Surface sampling in mainly *Acrostichum aureum* vegetation, Tanjung Lumpur, Kuantan.

swamp is observed developed on a probable former estuary-end of an impeded river channel. Morphologically, upriver the channel orientation shows that it was formerly very likely connected to the present Sungai Penur, which presently has an estuary further south (Fig. 5.15). Upon closure of the old Sungai Penur outlet, the river meanders its way for a new exit. At the present outlet of Sungai Penur it is observed that the river mouth is narrowly shrunk and also almost clogged from the presence of sand bars. These features are common for small river and stream outlets along the east coast. They are greatly influenced by the offshore waves and longshore currents depositing sediments along the coasts especially after strong storms and squalls.

Three surface samples KUPS13, KUPS14 and KUPS15 were collected from the waterlogged swamp bottom (Fig. 5.22). Their respective elevations are 3.566, 3.740 and 3.756 m MSL (Table 5.4). The sampled sediments are silty and very sandy.

5.4.2 Fossil Sites

The coring sites are located about 15 and 22 km SSW of Kuantan town (Fig. 5.13), called Penor (north) and Penor (south) respectively. Both transects are made by the roadside, the only relatively 'dry' place, over the swampy coastal plain.

Che Ghani (1981) recorded more than three Quaternary sedimentary depositional successions from deep boreholes (using semi-mechanised drilling equipment and exceeding 30 m depth) in transects across the Kuantan coastal plain. Near the coast, from bottom to top, the sequence consists of the lower continental unit, marine unit, continental unit, marine unit and the upper-most beach deposits. Somewhat inland, three successions are indicated, from bottom-up, represented by the continental unit, the marine clay and the organic rich or peat layer forming the top cover. However, no radiometric dating was reported from the study.

5.4.2.1 Penor (north) Stratigraphic Transect

Five boreholes, KUC16, KUC11, KUC9, KUC15 and KUC7, formed the Penor (north) transect (Fig. 5.23). The boreholes depth ranges from 2.9 m (KUC16) to 5.3 m (KUC7). The transect runs approx. NNW-SSE and spans about 2.3 km distance, while the interval between each successive cores varies between 450 m to

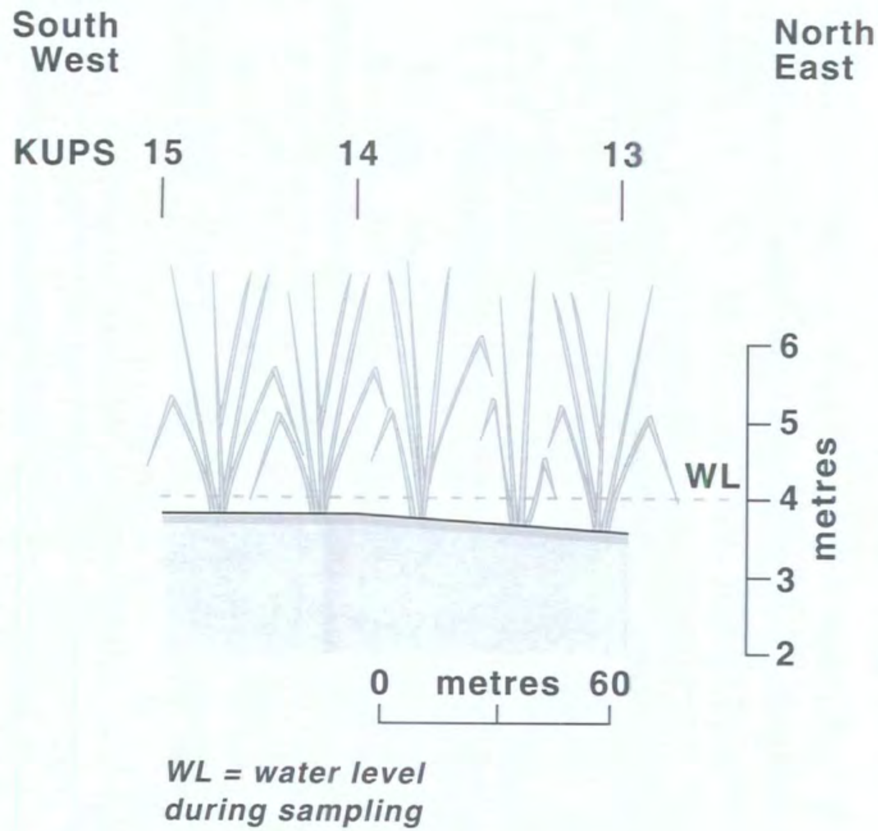


Fig. 5.22 Surface sampling in *Pandanus* swamp, Penor (south), Kuantan.

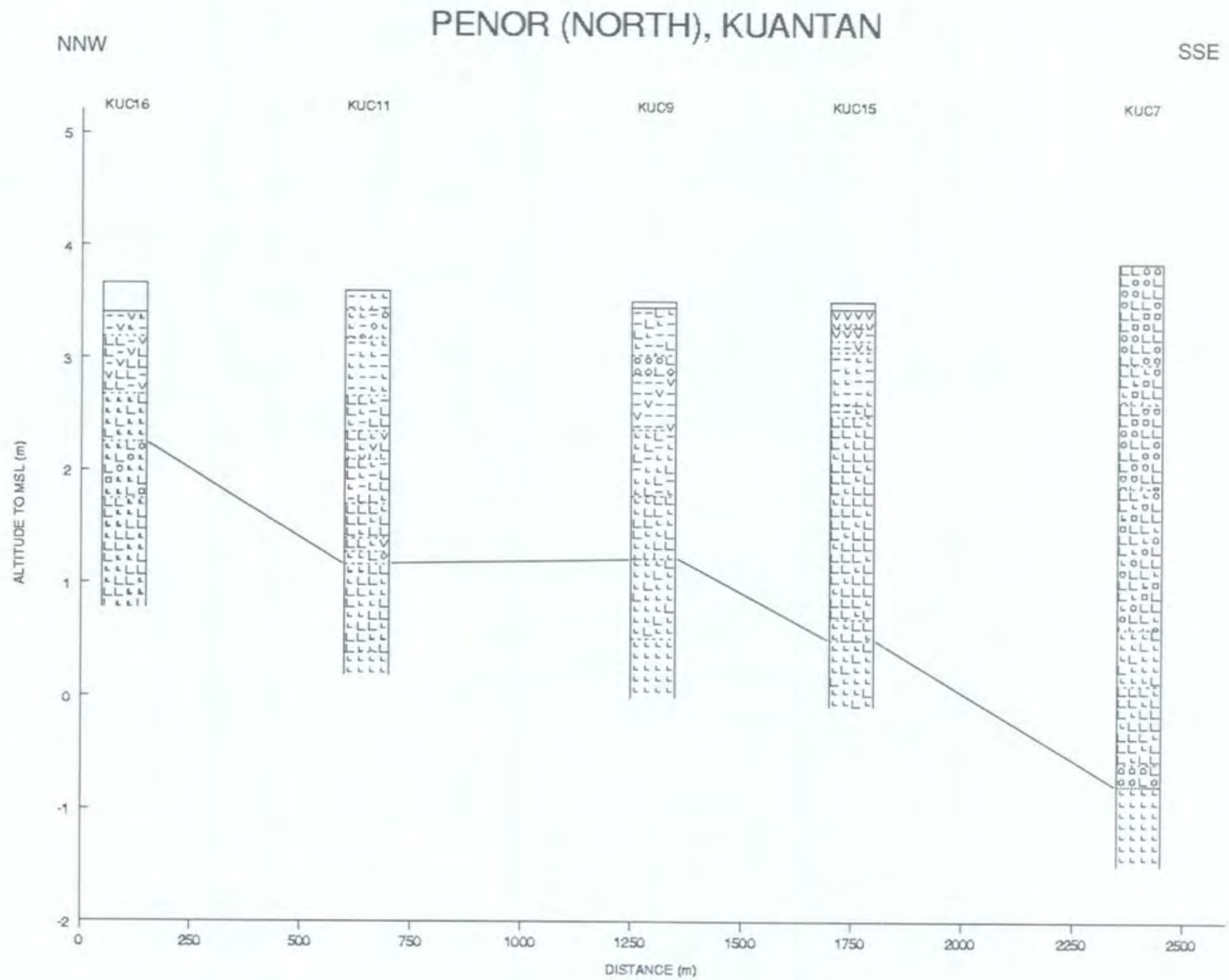


Fig. 5.23 Stratigraphic transect in Penor (north), Kuantan.

650 m. The ground surface is fairly flat with reduced core heights ranging from 3.514 m in KUC15 to 3.866 m MSL in KUC7.

In Penor (north) transect, the lithostratigraphy indicates at least two sediment sequences. The lowest sequence is represented by bright yellowish brown and dark red mottled, firm to stiff grey clay. This is overlain by yellowish grey to very dark brown slightly humic to peaty, clayey and silty sediments. In KUC9 and KUC15 thin clayey peat, about 50 cm, forms the top-most layer. The lithology of KUC7 is quite different from the other boreholes within the transect. This is probably related to its location near the confluence of a stream and Sungai Soi (Fig. 5.13), which probably influences the pattern of sedimentation. The lithology is consecutively represented (from bottom to top) by the lowest mottled clay followed by greenish grey marine clay, the mottled sandy layers, which in turn overlain by the greenish grey silty sand and finally the mottled silty sand.

Since not much biostratigraphic information is known from the east coast, the selection of sampling levels posed a difficult task. This was further added by the unclear lithological characteristics between the marine and the terrestrial sequences, as compared to that displayed in the west coast. The typical grey to greenish grey and 'smelly' marine clay of the west coast is not very characteristic in the east coast. Thus, in the transect only one core, KUC15, was selected for sampling. As a precautionary measure and to avoid repeating sampling, the whole length of the core was sampled. Fossil analyses of the core, especially if it is done throughout the sampled length, would certainly elucidate and assist future biostratigraphic study of the area.

5.4.2.2 Penor (south) Stratigraphic Transect

Five boreholes, KUC17, KUC12, KUC13, KUC14 and KUC18 oriented NNW-SSE, made up the Penor (south) transect (Fig. 5.24). The transect spans approx. 1.9 km and the distance between respective cores is about 400-500 m. The cores are rather shallow, ranging in depth from 2.2 to 2.9 m. All the cores bottom on light grey stiff sandy clay, where deeper penetration is very difficult. The ground surface shows lowering towards the south, but overall is elevated higher compared to the Penor (north) transect. The reduced level ranges from 5.984 in KUC17 to 4.881 m MSL in KUC18.

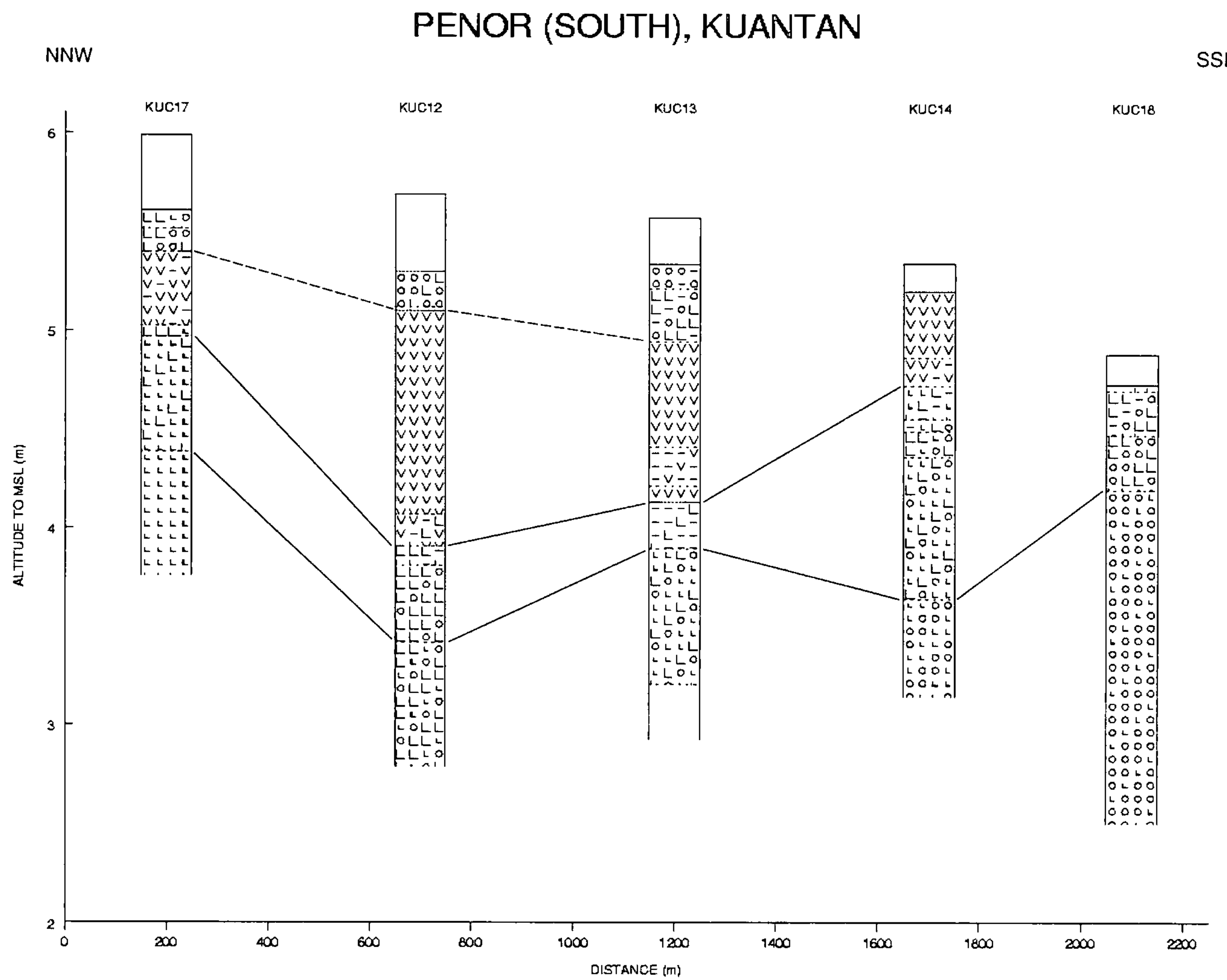


Fig. 5.24 Stratigraphic transect in Penor (south), Kuantan.

In the transect, at least two main lithostratigraphic sequences are distinguished. In KUC17, KUC12 and KUC13, four layers are recognised, three in KUC14 and two in KUC18. Stiff sandy clay forms the basal layer of the transect. Overlying the layer are yellowish grey to black clastic sediments, which in turn are overlain by a woody peat layer. The peat is brownish black to black with a thickness of 31 cm (KUC17) to 1.2 m (KUC12). In KUC 18 the peat layer is absent. In KUC17, KUC12 and KUC13, sandy clastics form the upper-most layer overlying the peat. Throughout the transect secondary infilled sediments littered the surface.

The peat layer in the profile shows a diffuse boundary with the underlying sediments, while the contact with the overlying layer is categorised as manifestus in KUC17, conspicuus in KUC12 and diffuse in KUC13 (scale of 2 to 0 of Troel Smith, 1955). Two cores, KUC17 and KUC12, were selected for sampling. Both cores were sampled throughout their length. Since the peat layers are not very thick and the total core lengths are accommodating, the whole core sampling was justified.

CHAPTER 6

MICROFOSSIL RESULTS

6.1 Introduction

In this chapter results of microfossil analyses of samples from Kelang and Kuantan from both contemporary and fossil pollen and diatoms are presented. The percentage count of the taxa in all the samples analysed is listed in Appendix 5. Figures 6.1 to 6.19 show the pollen and diatom frequency diagrams of the surface and core samples. The diagrams are referred to in all descriptions of the results. In all the diagrams only species or types represented by more than 2% are plotted. Figures 6.20 to 6.25 show the microfossils identified in the study.

6.2 Sample Analysis Summary

A total of 118 contemporary and fossil samples were analysed, 84 palynologically and 34 for diatom content. Simplified descriptions of the analysed samples are presented in Table 6.1. Detailed descriptions of the samples that were processed and analysed are listed in Appendix 2. For practical reasons and ease of comparison between the pollen and diatom data, the samples were as far as possible studied at similar altitudinal levels.

Table 6.1. Simplified number of samples analysed.

	Number of Samples	
Transect \ Analysis	Palynology	Diatoms
Kelang-contemporary	12	9
Meru-fossil	12	8
Mardi-fossil	26	Analysed but rare/nil
Kuantan-contemporary	17	17
Penor (north)-fossil	11	Analysed but rare/nil
Penor (south)-fossil	6	Analysed but rare/nil
Total	84	34

In pollen analysis, pollen and spores are present in moderate to abundant amounts in both the contemporary and fossil samples. However in diatom analysis moderate to abundant diatom valves were only present in the contemporary samples. Apart from the Meru transect, diatoms were rare or absent in all other fossil transects analysed. The latter could be due to the diatom preservation condition or probably purely the absence of diatoms. In the Kelang area, it is quite puzzling to find diatoms in Meru and not Mardi considering they both show a rather similar environment of deposition.

A total of 139 pollen types and 61 diatom taxa are differentiated. The palynomorphs and diatoms, both contemporary and fossil, are summarised into their ecological assemblages and are presented in Appendix 4. The ecological classifications of the pollen types are based on the environment where the vegetation commonly thrives. The seven ecological divisions differentiated are mangrove, coast, back mangrove, coastal freshwater swamp, swamp and lowland, lowland open and inland (Appendix 4.1). Palynomorphs like acritarch, dinoflagellate cysts, foraminifera inner tests and *Tasmanitids* type are categorised in the mangrove. Generally, these palynomorphs are very rare, when found they commonly formed <2% of the pollen sum. Nevertheless, in surface samples KES13 and KUS9, foraminifera inner tests occur at about 3%. *Chomotriletes* sp., also very rarely found (<2%), is classified as the back mangrove. The unidentified pollen types, which include the unknown, broken, corroded, folded and hidden, commonly comprise less than 10% of the pollen sum. Because of the rather low numbers, the unidentified pollen types are not separately distinguished but included in the inland category. Also, the unidentifieds are assumed to represent the more than 7500 species of estimated total flora present in the peninsula (Whitmore, 1972a). Apart from the unknown types, which themselves were probably derived from the inland, the broken, corroded and folded grains are assumed the result of long distance transport, very likely by streams and rivers from the inland sources. In northwest Europe the indeterminable pollen types are commonly excluded from the total land pollen (Waller, 1994). In Kuantan surface samples quite high percentages, up to 15% of the pollen sum, of the unidentified types are, however, recorded. The rather high amount, nevertheless necessitate explanation on whether it is appropriate to include or exclude the unidentifieds to/from the inland assemblage. Using 38 (unidentifieds included in the inland) and 33 (unidentifieds excluded from the inland) pollen and spore types that exceed 2% pollen sum, CONISS (constrained incremental sum of squares cluster analysis) indicated quite similar dendrograms between the two.

Differences in their cluster dispersions are very low and do not at all influence the pollen zonation (Figs. 6.2 & 6.3). Even though the exclusion of the unidentifieds from the inland would be more tangible, the inclusion of the unidentified pollen types in the inland category is acceptable since the latter shows a negligible effect to the overall pollen frequency diagram. The fern and fungal spores are also plotted in the pollen diagram, their frequencies calculated to the pollen sum. Except for *Acrostichum aureum*, the fern and fungal spores are not ecologically differentiated (Appendix 4.2). Appendix 4.3 lists both the contemporary and fossil diatom species, classified according to their salinity tolerance and life forms.

6.3 Contemporary Pollen

A total of 29 surface samples, 12 from Kelang and 17 from Kuantan were analysed. The palynological results from the different ecological sites for the respective areas are presented graphically according to the levelled heights, as tabulated in Table 6.2. Figures 6.1 and 6.2 show the contemporary pollen diagrams of the Kelang and Kuantan study areas.

Table 6.2. Microfossil analysis of contemporary samples from Kelang and Kuantan.

Kelang				Kuantan			
Sample no.	Altitude (m)	Pollen	Diatom	Sample	Altitude (m)	Pollen	Diatom
KES18	2.181	✓	✓	KUPS15	3.756	✓	✓
KES21	1.927	✓	na	KUPS14	3.740	✓	✓
KES17	1.801	✓	✓	KUPS13	3.566	✓	✓
KES19	1.759	✓	na	KUS16	1.799	✓	✓
KES16	1.449	✓	✓	KUS17	1.777	✓	✓
KES20	1.439	✓	na	KUS18	1.465	✓	✓
KES15	0.926	✓	✓	KUS15	1.334	✓	✓
KES13	0.740	✓	✓	KUS19	1.100	✓	✓
KES11	0.542	✓	✓	KUS20	1.098	✓	✓
KES9	0.335	✓	✓	KUS13	0.999	✓	✓
KES7	0.138	✓	✓	KUS11	0.862	✓	✓
KES3	-0.095	✓	✓	KUS9	0.723	✓	✓
				KUS21	0.709	✓	✓
				KUS7	0.505	✓	✓
				KUS5	0.147	✓	✓
				KUS3	-0.263	✓	✓
				KUS1	-0.620	✓	✓

✓=sample analysed na=sample not analysed

6.3.1 Kelang

Figure 6.1 shows the combined contemporary pollen diagram of the Jeram mangrove coast and the Pantai Remis *Nypa* vegetation in Kelang (see also Figs. 5.6 & 5.7). Using the 39 pollen and spore types that exceed 2% pollen sum, CONISS identified three pollen zones. The pollen zones are denoted, A, C and D. B merely represents the large no sampling gap between KES13 and KES20. The results of KES15 is not included in the pollen diagram since only 37 pollen grains were counted from 2 slides analysed.

Zone A shows the predominance of *Rhizophora* spp., from 17-28% of the pollen sum. In the zone, mangrove types show highest representation within the transect, constituting 25-42%. Within the zone, in sample KES11, the coastal pollen type *Casuarina equisetifolia* shows its maximum frequency of 14%. Zone A corresponds to the tidal level from about MSL to about MHWN (Table 6.3).

Table 6.3. Relation of microfossil zones and tidal levels for contemporary Kelang samples.

Sample no.	Vegetation transect	Altitude (m)	Tidal level (m)	Pollen zone	Diatom zone
		2.683	EHW		
KES18	embankment side	2.181		D	C
		2.113	MHWS		
KES21	*Nypa* vegetation	1.927		C	-
KES17	mangrove tidal swamp	1.801		C	C
KES19	*Nypa* vegetation	1.759		C	-
		1.463	mid of MHWN to MHWS		
KES16	mangrove tidal swamp	1.449		C	C
KES20	*Nypa* vegetation	1.439		C	-
KES15	mangrove tidal swamp	0.926		-	A
		0.813	MHWN		
KES13	mangrove tidal swamp	0.740		A	A
KES11	mangrove tidal swamp starts	0.542		A	A
KES9	unvegetated tidal flat	0.335		A	A
KES7	unvegetated tidal flat	0.138		A	A
		0	MSL		
KES3	unvegetated tidal flat	-0.095		A	A
		-0.707	MLWN		

Zone C shows abundance of *Oncosperma tigillarium*, the back mangrove pollen type. It predominates (34-47%) in all the three samples (KES19-21) from the

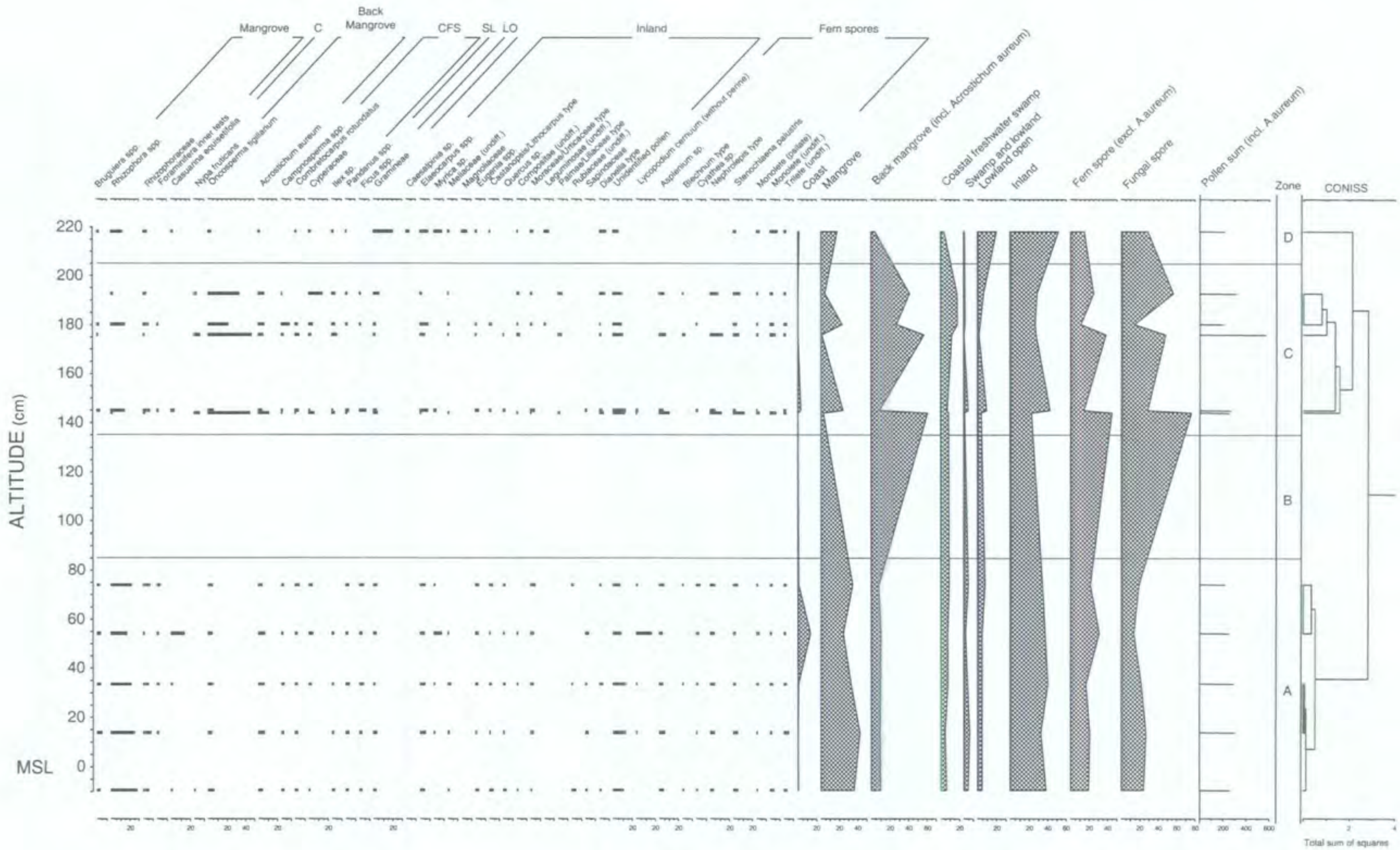


Fig. 6.1 Pollen diagram of Kelang contemporary samples.

Nypa vegetation. In the mangrove tidal swamp transect, *Oncosperma tigillarium* is significant (22%) in only one sample, KES17. Also in zone C, the coastal freshwater swamp, inland pollen types, fern and fungal spores increase. Meanwhile, the mangrove assemblage shows decreasing values (18-24%) from the mangrove transect, while very low frequencies (1-4%) in the *Nypa* vegetation. In the former, *Rhizophora* spp. constitute about 14-15% of the pollen sum. Zone C coincides with approximately the upper-half of the MHWN to MHWS tidal zone (Table 6.3).

Zone D is formed by only one sample, KES18. Gramineae shows its highest representation, 20%, which correspond to increase in the lowland open pollen type. Inland pollen too increases, while mangrove and back mangrove types decreases.

6.3.2 Kuantan

Figure 6.2 shows the Kuantan contemporary pollen diagram erected from the mangrove, *Nypa* swamp, *Acrostichum aureum* vegetation and *Pandanus* swamp combined (see also Figs. 5.17-5.20). The CONISS cluster analysis, using 38 pollen and spore types exceeding 2% pollen sum, identified three pollen zones. The pollen zones are denoted A, B and D. As in Fig. 6.1, C is merely added to indicate the large sampling gap between KUS16 and KUPS13.

In zone A *Rhizophora* spp. predominates, constituting 22-55% of the pollen sum. Consequently mangrove types dominate the zone, forming 39-67%. The coastal freshwater swamp specie, *Combretocarpus rotundatus* is well represented in the zone (4-19%). *Acrostichum aureum* (back mangrove), *Calophyllum* sp. (coastal freshwater swamp), *Combretocarpus rotundatus* and *Eugenia* spp. (inland) show their maximal in representation, notably above MHWS level. Inland pollen type is also well represented (13-39%). Zone A corresponds to sampling level from above MLWS to slightly above mid way between MHWS to EHW level (Table 6.4).

Zone B shows the predominance of Cyperaceae (59-83%). Consequently the coastal freshwater swamp type, to which Cyperaceae belongs, shows its peak value (65-85%). This maxima is indicated by two samples, KUS16 & KUS17, from the *Acrostichum aureum* and grasses vegetation type. In the zone, mangrove and inland types show a drastic reduction while other ecological groups are insignificant. Zone B corresponds to around the EHW tide level (Table 6.4).

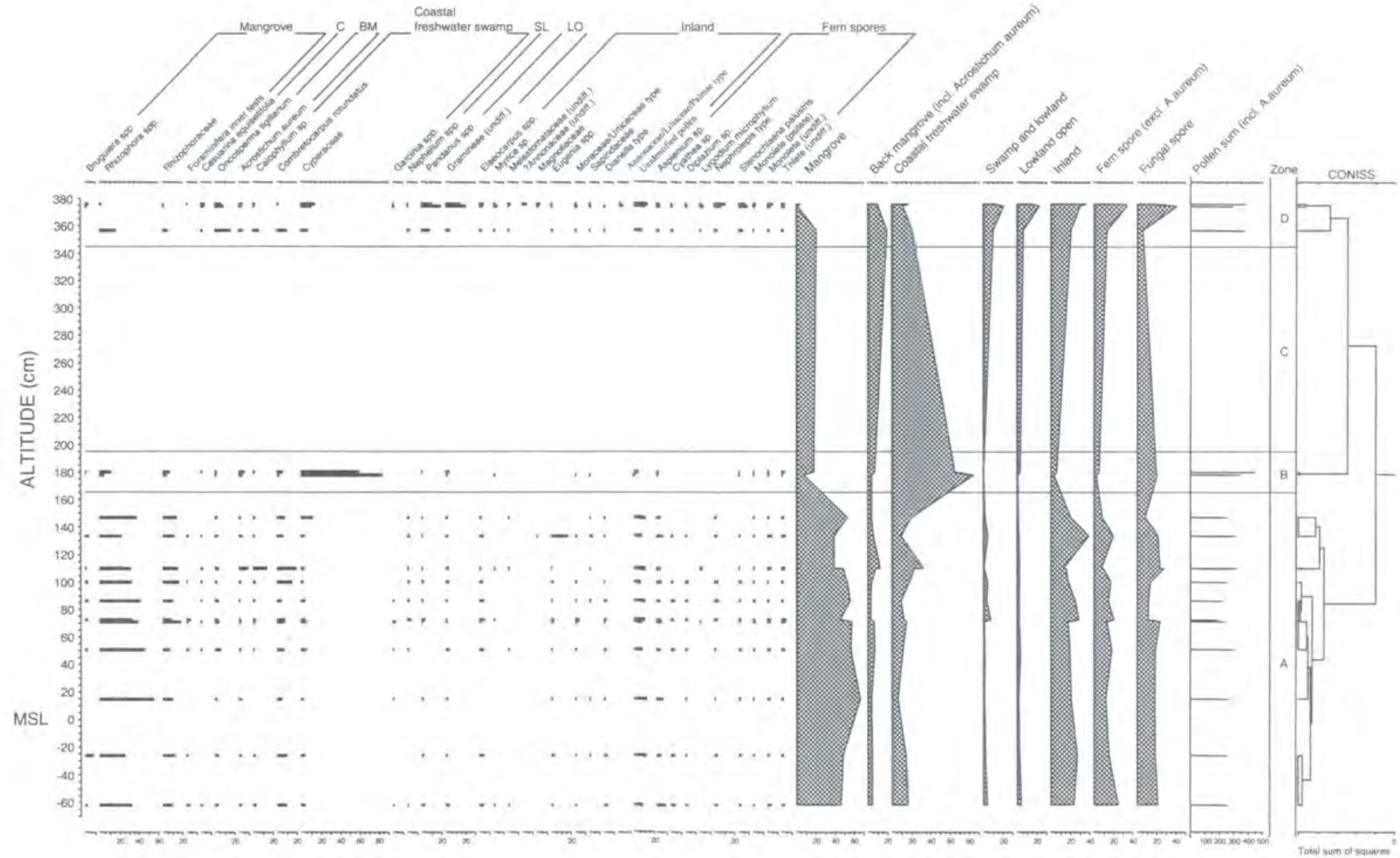


Fig. 6.2 Pollen diagram of Kuantan contemporary samples.

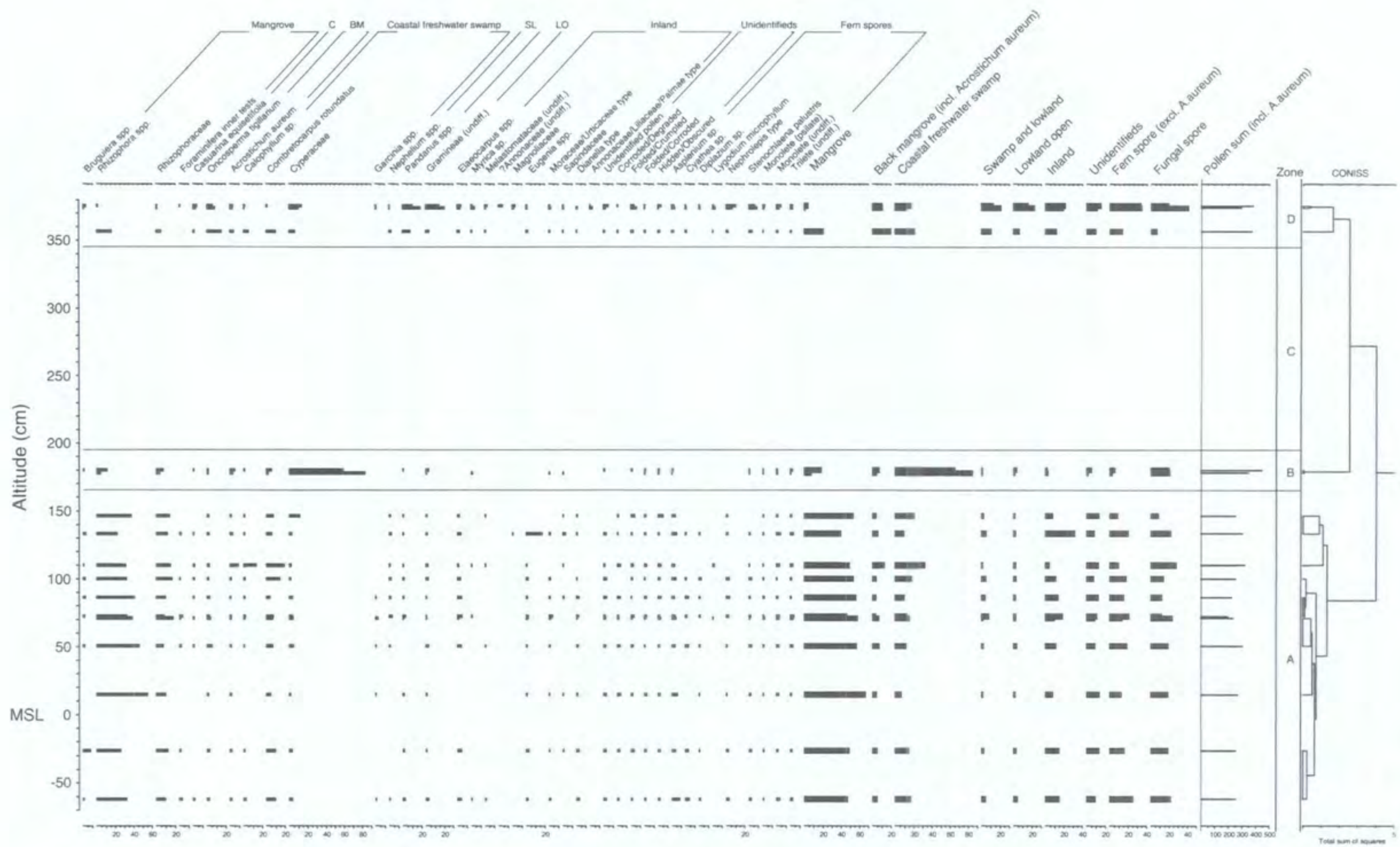


Fig. 6.3 Pollen diagram of Kuantan contemporary samples, with the unidentified pollen types excluded from the inland group.

Zone D characterises the coastal *Pandanus* swamp samples (Table 5.2 & 6.2). Peak values are indicated by *Pandanus* spp. (19%), Gramineae (20%), and *Oncosperma tigillarium* (15%), otherwise they constitute only <3-5% throughout the rest of the transect. Fern and fungal spores also show their maximum representation in the zone. The swamp is above the high tide level but its close location to the sea explains the high *Oncosperma tigillarium,* and considerable *Rhizophora* spp. (16%) in one of the samples.

6.4 Contemporary Diatom Assemblages

A total of 26 surface samples were analysed, 9 from Kelang and 17 from Kuantan (Tables 6.1 and 6.2). The results are plotted graphically as diatom diagrams (Figs. 6.4-6.7). Two types of diagram, salinity and life form, are presented for each study area.

6.4.1 Kelang

Figures 6.4 & 6.5 show the diatom diagrams of 9 samples analysed from the Jeram mangrove coast. The CONISS of 13 species that exceed 2% TDV, differentiated 2 diatom zones, defined at similar levels in both the salinity and life form diagrams. The diatom zones are denoted A and C. An additional level, B, is however added to represent the significant sampling gap between KES15 and KES16.

In the salinity diagram, two distinct diatom groups are differentiated. Zone A shows the predominance of the polyhalobous diatom assemblages forming 62-71% of TDV, mainly represented by *Thalassionema nitzschioides* (31-46%), *Cyclotella striata* (18-26), *Trybilioptychus cocconeiformis* (8-13%), *Coscinodiscus blandus* (5-15%) and *Delphineis surirella* (4-11%). In zone C mesohalobous diatoms predominate (90-96%), chiefly comprise of *Acnanthes delicatula* (55-70%) and *Amphora coffeaeformis* (24-34%).

For the life form diagram, zone A shows predominating planktonic assemblages (87-90% TDV). Meanwhile zone C shows predominant episammic (55-

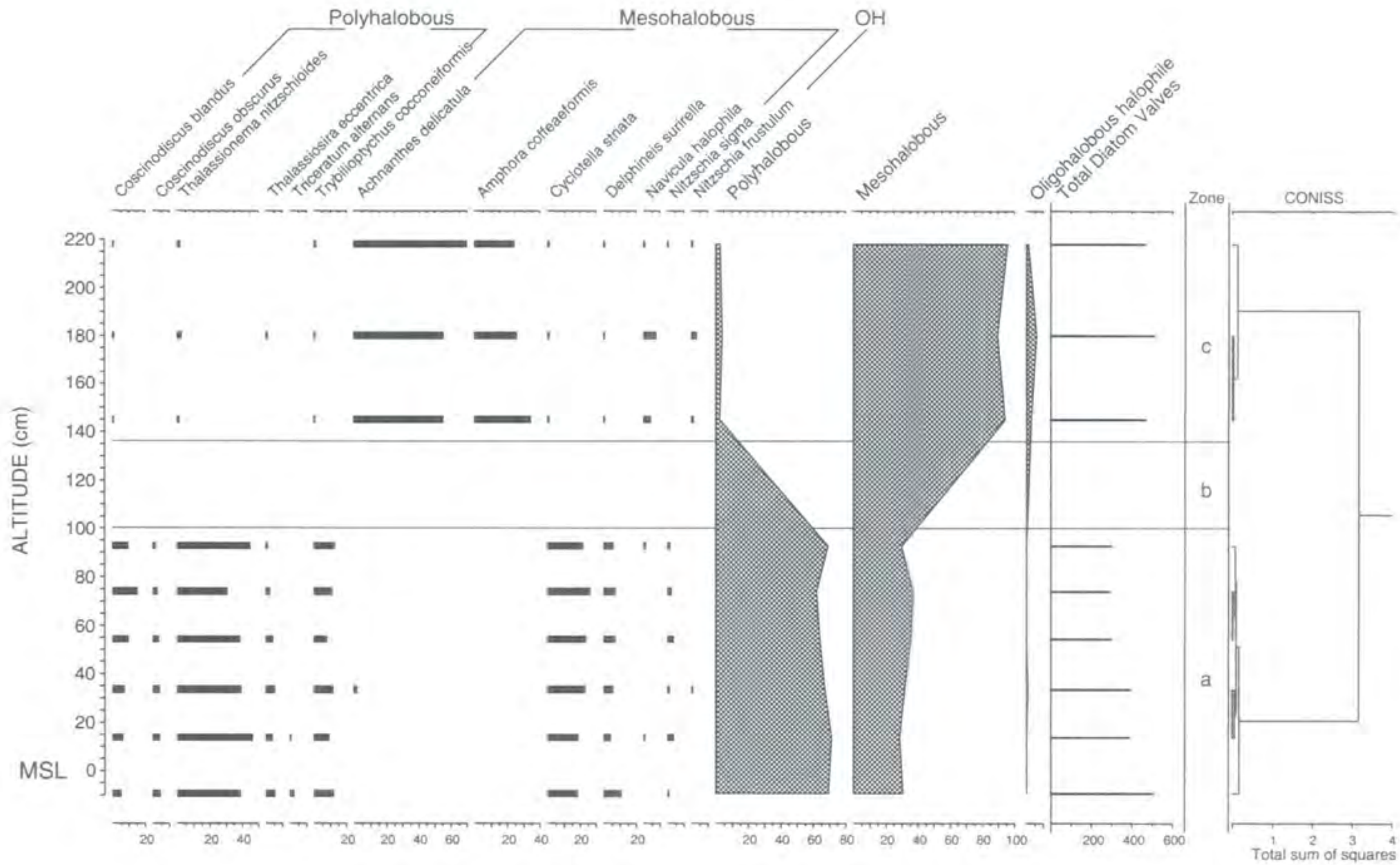


Fig.6.4 Diatom diagram (salinity) of Kelang contemporary samples.

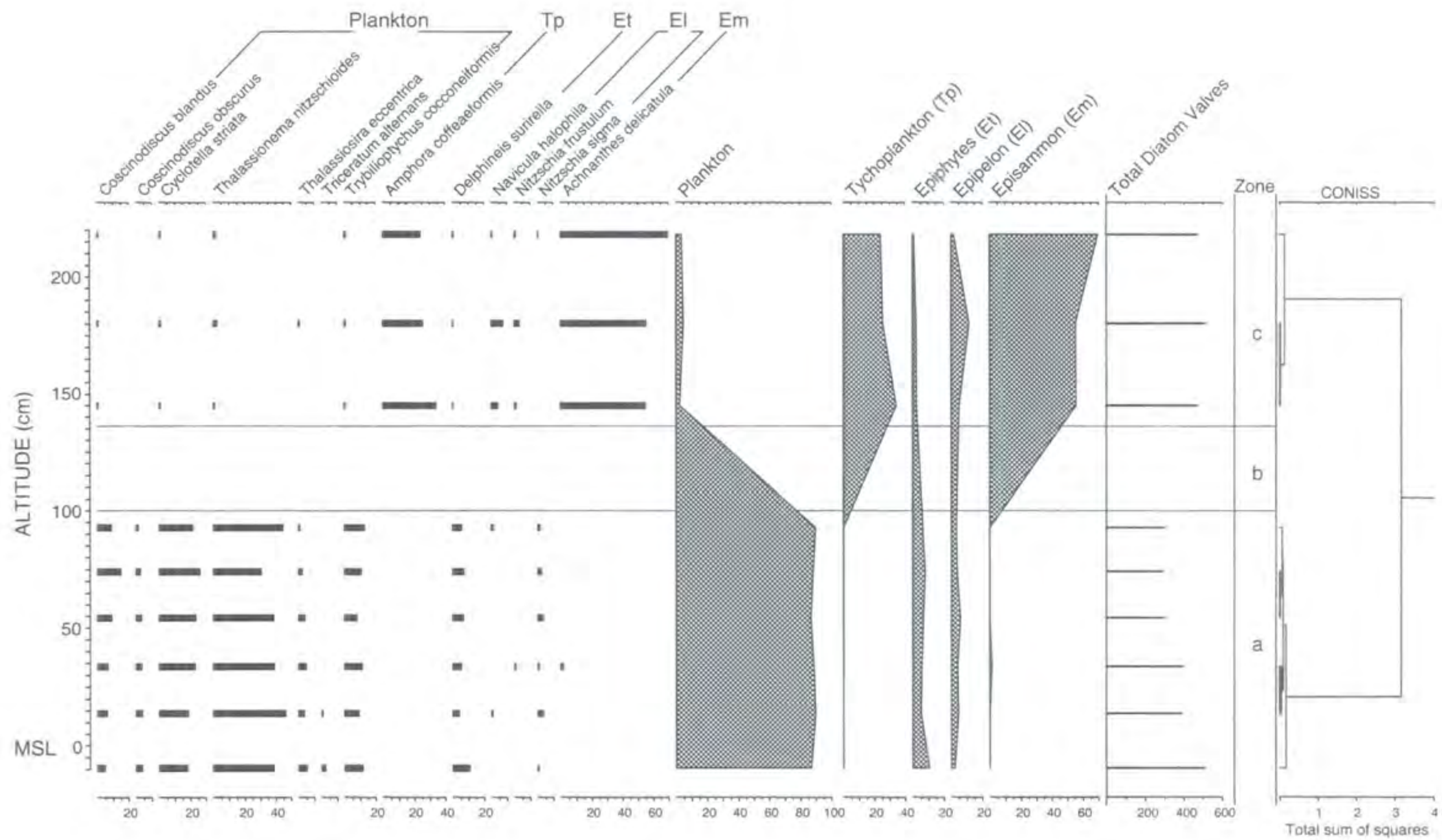


Fig. 6.5 Diatom diagram (life form) of Kelang contemporary samples.

70%) and abundant tychoplanktonic (24-34%) taxa. Other life forms, the epiphytic and epipelic diatoms, do occur but they are not very significant.

Zone A in both diatom diagrams is depicted around the MSL to MHWN tidal level while zone C represents approximately the upper half of the MHWN to MHWS positions (Table 6.3).

6.4.2 Kuantan

Figures 6.6 and 6.7 show the diatom diagrams of the 17 samples from the mangrove, *Nypa* swamp, *Acrostichum aureum* vegetation and *Pandanus* swamp. Based on CONISS of 35 species exceeding 2% TDV, the diagrams (both of the salinity and life form) are similarly divided into 5 zones. The pollen zones are denoted A, B, C, D and F. The interval E, between zones D and F, represents the large sampling gap between KUS16 and KUPS13.

Zone A of the salinity diagram (Fig. 6.6) shows a predominant polyhalobous assemblage (69-70% TDV), mainly represented by *Thalassionema nitzschioides* and *Coscinodiscus blandus*, with abundant mesohalobous species (30-31%) chiefly represented by *Cyclotella striata.* In zone B the mesohalobous diatoms dominates (44-75%), *Amphora coffeaeformis* and *Achnanthes delicatula* form the most prominent taxa. The polyhalobous taxa decrease (7-41%) while significance presence of oligohalobous halophile diatoms (7-14%) is indicated. Meanwhile in zone C, high proportions of the polyhalobous (30-42%) and mesohalobous diatoms (39-40%) and significant oligohalobous halophile taxa are shown. In zone D a oligohalobous indifferent assemblage is predominant (95-100%), represented by *Navicula avonensis, Nitzschia pusilla, Nitzschia parvula* and *Pinnularia obscura.* Other assemblages are insignificant. Zone F shows the only occurrence of the halophobous diatoms (42-52%), denoted by *Frustulia rhomboids*, *Pinnularia subcapitata* and *Eunotia monodon.* Also, oligohalobous indifferent diatoms (35-55%) dominate, mainly made up of *Eunotia tenella*, while oligohalobous halophile (3-13%) taxa are present.

In the life form diagram (Fig. 6.7), zone A is dominated by planktonic (62-68%) and epipelic (15-22%) diatoms, while others are insignificant. In zone B, tychoplankton (22-53%) and epipelic (18-43%) assemblages are most abundant. The planktic taxa are reduced (5-36%) whereas the episammic taxa are significant. Zone

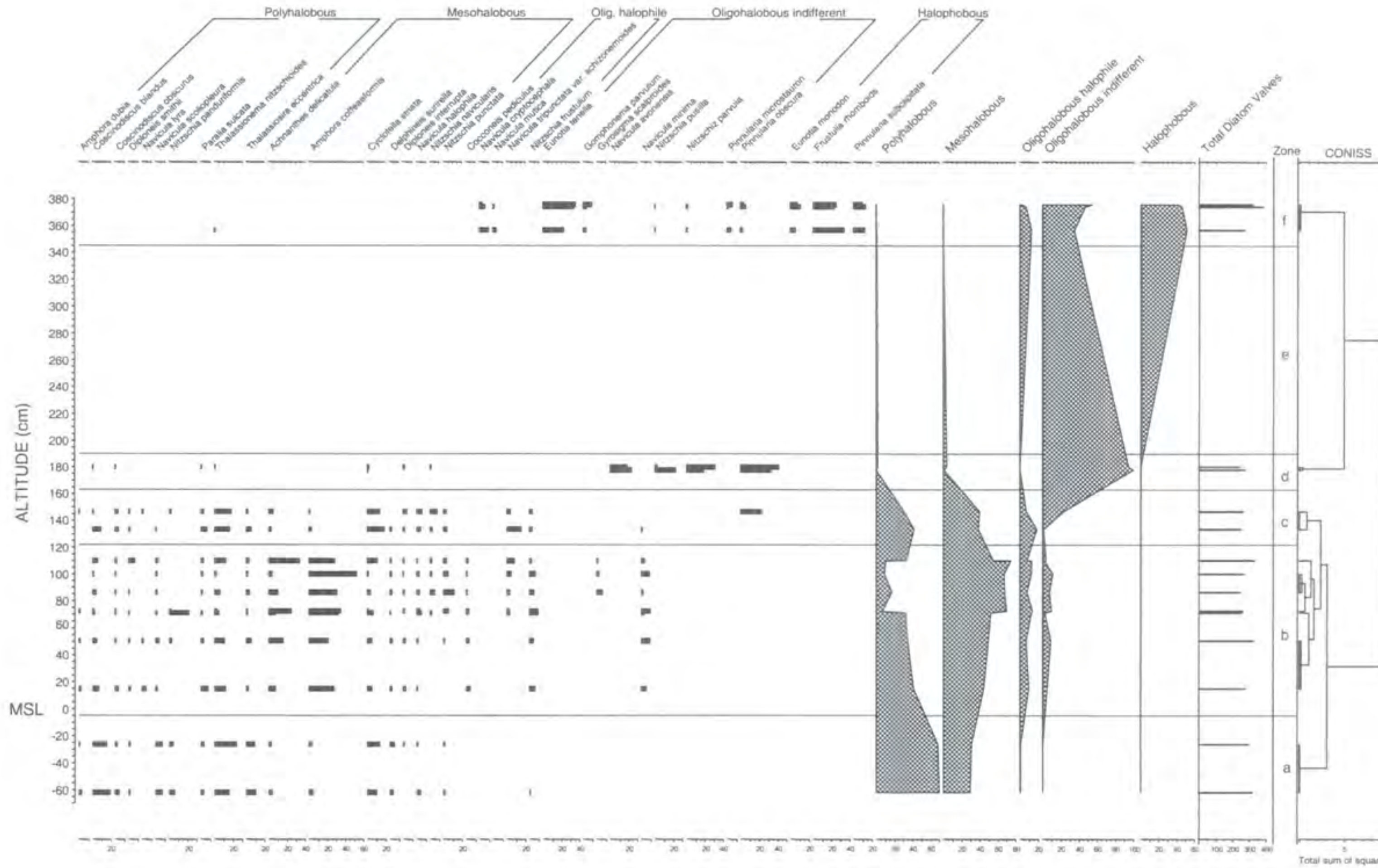


Fig. 6.6 Diatom diagram (salinity) of Kuantan contemporary samples.

Fig. 6.7 Diatom diagram (life form) of Kuantan contemporary samples.

C shows abundant plankton (41-59%) epipelic (26-32%) diatoms and a significant increase of the aerophilous (to 26%) assemblage. Zone D shows predominance of epipelic (55-67%) and aerophilous (33-42%) diatoms. Zone F exhibits the maximum frequency of epiphytic diatoms (33-53%) and abundant epipelic (28-49%) and aerophilous (18-19%) types.

The zonal patterns of both the diatom diagrams (Figs. 6.6 & 6.7) appear to approximately coincide with the vegetation and tidal levels. Zone A correlates with the unvegetated mangrove tidal flat or a position lower than MSL. Zone B with the vegetated mangrove and *Nypa* swamps from about MSL to mid way between MHWS and EHW levels, zone C from mid to ¾ of MHWS to EHW, zone D to the *Acrostichum aureum* vegetation or around the EHW levels, and zone F to the supratidal coastal *Pandanus* swamp. Their relations are simplified in Table 6.4.

Table 6.4. Relation of microfossil zones and tidal levels for contemporary Kuantan samples.

Sample no.	Vegetation transect	Altitude (m)	Tidal level (m)	Pollen zone	Diatom zone
KUPS15	coastal *Pandanus* swamp	3.756		D	F
KUPS14	coastal *Pandanus* swamp	3.740		D	F
KUPS13	coastal *Pandanus* swamp	3.566		D	F
		1.816	EHW		
KUS16	*A. aureum* vegetation	1.799		B	D
KUS17	*A. aureum* vegetation	1.777		B	D
		1.571	¾ of MHWS to EHW		
KUS18	*A. aureum* vegetation	1.465		A	C
KUS15	mangrove tidal swamp	1.334		A	C
		1.326	mid of MHWS to EHW		
KUS19	*Nypa* swamp	1.100		A	B
KUS20	*Nypa* swamp	1.098		A	B
KUS13	mangrove tidal swamp	0.999		A	B
KUS11	mangrove tidal swamp	0.862		A	B
		0.836	MHWS		
KUS9	mangrove tidal swamp	0.723		A	B
KUS21	*Nypa* swamp	0.709		A	B
KUS7	mangrove tidal swamp	0.505		A	B
		0.426	MHWN		
KUS5	start of mangrove roots	0.147		A	B
		0	MSL		
KUS3	unveg. tidal river bank	-0.263		A	A
		-0.434	MLWN		
KUS1	unveg. tidal river bank	-0.620		A	A
		-0.764	MLWS		

6.5 Fossil Pollen

A total of 55 samples from the Kelang and Kuantan study sites were analysed. As indicated in Table 6.1, 38 samples are from the Meru and Mardi transects in Kelang, while 17 samples from the Penor (north and south) transects in Kuantan (see also Figs. 5.8, 5.9, 5.21 & 5.22). The results of the analyses are displayed graphically in Figs. 6.8 to 6.15. Stratigraphically constrained incremental sum of squares cluster analyses (CONISS) were carried out (for the >2% of the pollen sum), to define the pollen assemblage zones.

6.5.1 Meru Transect

In the Meru transect two cores, KEC1 and KEC2, were investigated. A total of 12 samples were analysed from both the cores. The samples were selected from within the regressive overlap boundaries of the respective cores. They are sampled from the base of the peat layer and the top of the underlying marine clayey/silty silt/clay layer (Fig. 5.8 and Appendices 1 & 2). Table 6.5 shows the analysed samples from the cores.

Table 6.5. Analysed pollen and diatom sample levels at Meru, Kelang.

Core KEC2				Core KEC1			
Depth (cm)	Altitude (m)	Pollen	Diatom	Depth (cm)	Altitude (m)	Pollen	Diatom
66	4.243	✓	✓ (rare)	105	4.354	✓	✓ (nil)
68	4.223	✓	✓	107	4.334	✓	✓ (rare)
70	4.203	✓	✓	109	4.314	✓	✓ (nil)
71	4.193	✓	✓	111	4.294	✓	✓
73	4.173	✓	✓	113	4.274	✓	✓
76	4.143	✓	✓	116	4.244	✓	✓

✓=sample analysed

6.5.1.1 Core KEC2

Figure 6.8 shows the pollen diagram of core KEC2. Three pollen zones, 1-3, are identified. In the diagram it is observed that mangrove and back mangrove assemblages form the most significant groups. From zone 1 to 3 or 76-66 cm depth

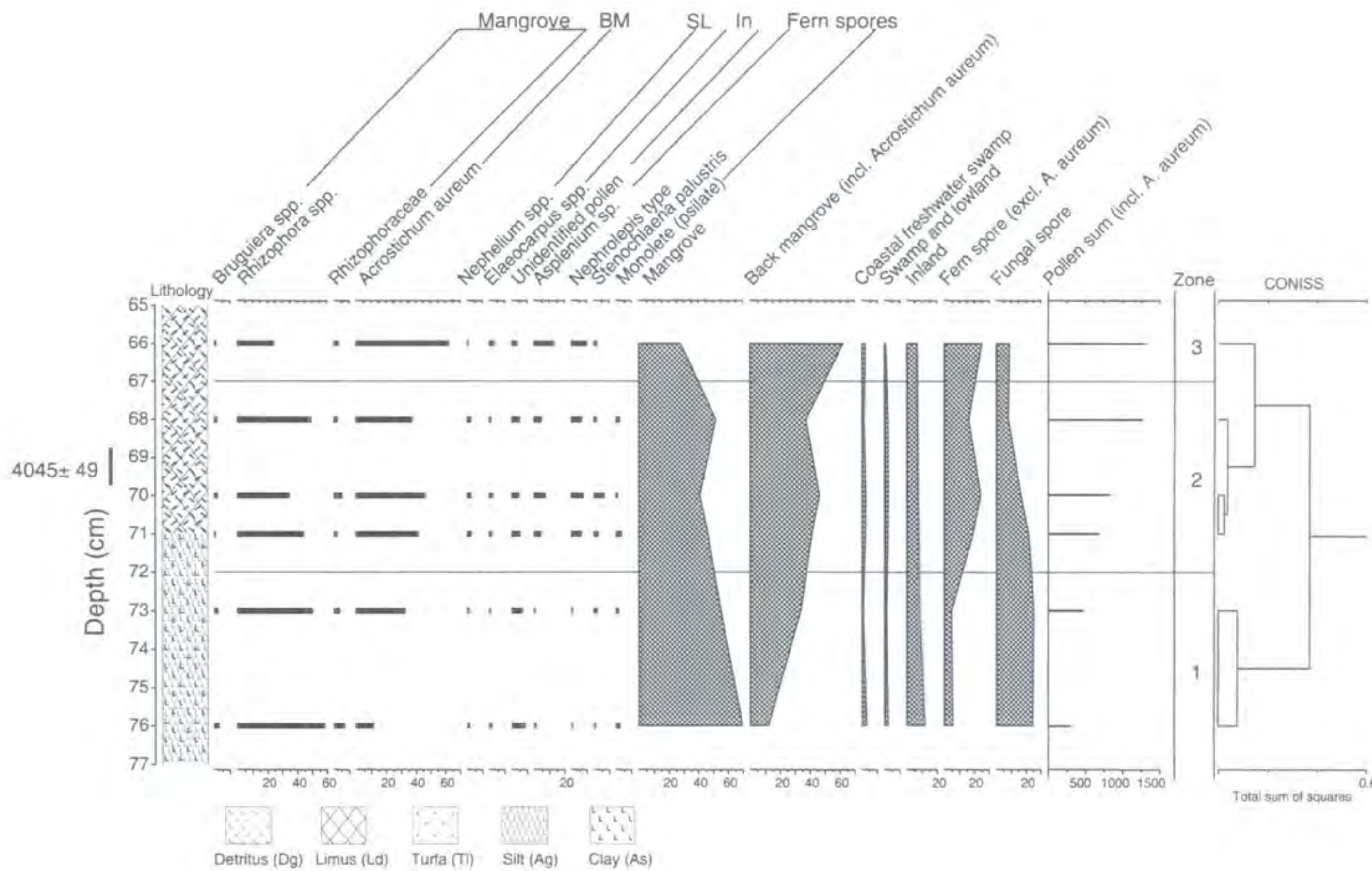


Fig.6.8 Pollen diagram of core KEC2, Meru, Kelang.

samples, apart from the depth at 68 cm, the profile of *Rhizophora* spp. shows a basically decreasing trend (from 58% to 24%), *Acrostichum aureum* increases (from 11% to 62%). In zone 1 mangrove predominates (55-70%) but in zone 3 the back mangrove constituent is dominant (62%). Meanwhile in zone 2, the mangrove (41-52%) and back mangrove (37-46%) are about equally represented. Also, in zone 2 some increase in fern spores but decrease in fungal spores are noted.

6.5.1.2 Core KEC1

The pollen diagram of KEC1 is shown in Fig. 6.9. The diagram is divided into three pollen zones, 1-3. Zone 1 is characterised by predominant mangrove assemblages (68-69%), where *Rhizophora* spp. made up 54-56%. Zone 2 shows domination of the back mangrove, *Acrostichum aureum*, constituting 59-84% and decrease of the mangrove types (8-26%). Zone 3 shows a decrease in the representation of the back mangrove, low in mangrove but a peak in the coastal freshwater swamp (17-23%), lowland open (26%), and inland (25-35%) and the fern and fungal spores.

6.5.2 Mardi Transect

In the Mardi transect four cores, KEC9, KEC8, KEC7 and KEC13 were investigated. As indicated in Table 6.1, a total of 26 samples were analysed, the detail of which is tabulated in Table 6.6. As in the Meru transect, the samples were also retrieved from within the regressive overlap boundaries of the respective cores. Figures 6.10-6.13 show the pollen diagrams of the analysed cores.

6.5.2.1 Core KEC9

The pollen diagram of KEC9 is shown in Fig. 6.10. The diagram is divided into three zones, 1-3, where zone 1 is subdivided into 1a and 1b. In the diagram, mangrove forms the most prominent assemblage, constituting 28-84% throughout the profile. Zone 1 shows the dominance of the mangrove. In zone 1b the mangrove starts to decrease while the swamp and lowland and inland assemblages begin to increase. Zone 2 shows decreasing mangrove (49%), while maximum values are

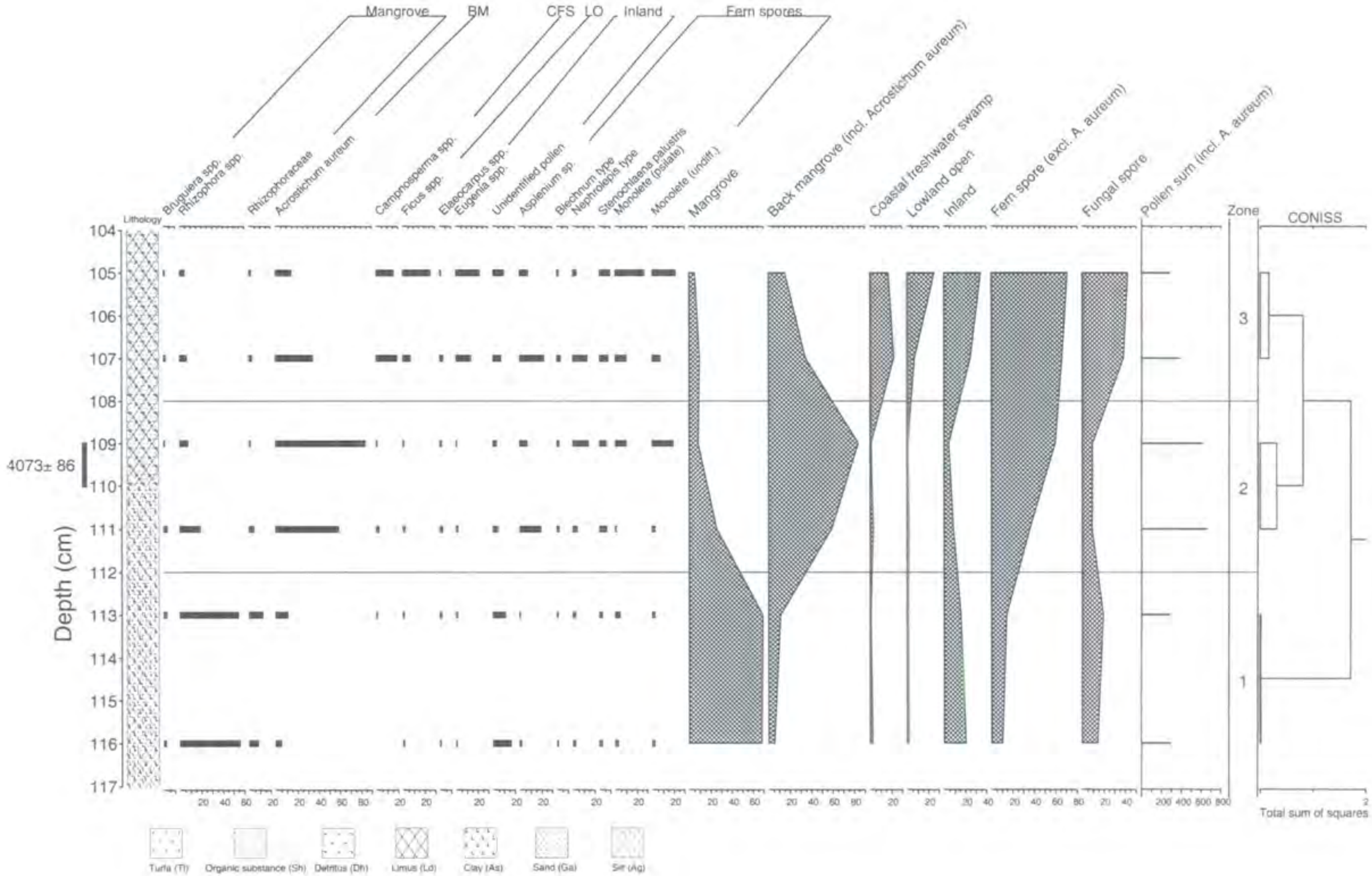


Fig. 6.9 Pollen diagram of core KEC1, Meru, Kelang.

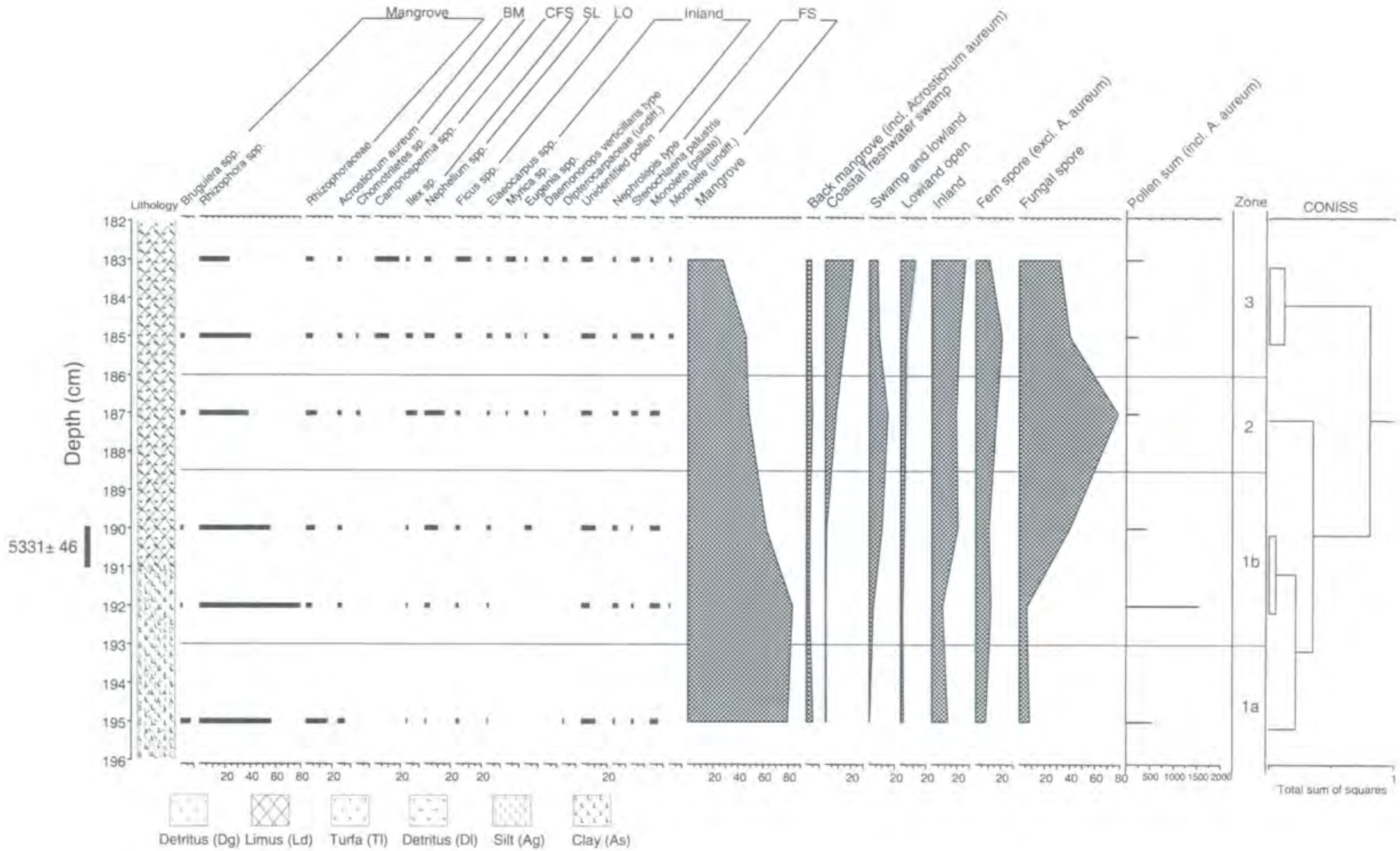


Fig. 6.10 Pollen diagram of core KEC9, Mardi, Kelang.

shown by the swamp and lowland assemblage (15%) and fungal spores. Zone 3 shows maximum representation of coastal freshwater swamp (16-22%), lowland open (5-12%) and inland (22-27%) assemblages.

Table 6.6. Analysed pollen sample levels at Mardi, Kelang.

Core KEC9		Core KEC8		Core KEC7		Core KEC13	
Depth (cm)	Altitude (m)	Depth (cm)	Altitude (m)	Depth (cm)	Altitude (m)	Depth (cm)	Altitude (m)
183	5.016	169	4.745	66	4.837	89	4.808
185	4.996	171	4.725	68	4.817	91	4.788
187	4.976	173	4.705	69.5	4.802	93	4.768
190	4.946	174.5	4.690	71	4.787	94.5	4.753
192	4.926	176	4.675	73	4.767	96	4.738
195	4.896	177	4.665	76	4.737	98	4.718
		180	4.635			100	4.698

6.5.2.2 Core KEC8

Figure 6.11 shows the pollen diagram of KEC8. Three pollen zones, 1-3, are recognised. Zone 1 shows the predominance of mangrove (91%). Zone 2 shows decreasing mangrove representation (71-34%) but a peak in the back mangrove (14-35%) and increasing assemblages of swamp and lowland (5-14%), inland (10-21%) and fern and fungal spores. Zone 3 shows low mangrove values (17-20%), and a peak in coastal freshwater swamp, swamp and lowland, inland and fungal spores, with high proportions of the back mangrove and fern spores.

6.5.2.3 Core KEC7

The pollen diagram of KEC7, shown in Fig. 6.12, is divided into three pollen zones, 1-3. Zone 1 shows predominance of the mangrove assemblage (46-62%). The back mangrove type is well represented (9-22%), and shows its peak at the top level of the zone, at 71 cm depth. Zone 2, represented by only one sample, shows decreasing mangrove and back mangrove components but increasing coastal freshwater swamp, inland and fern spores assemblages. In zone 3, mangrove and the

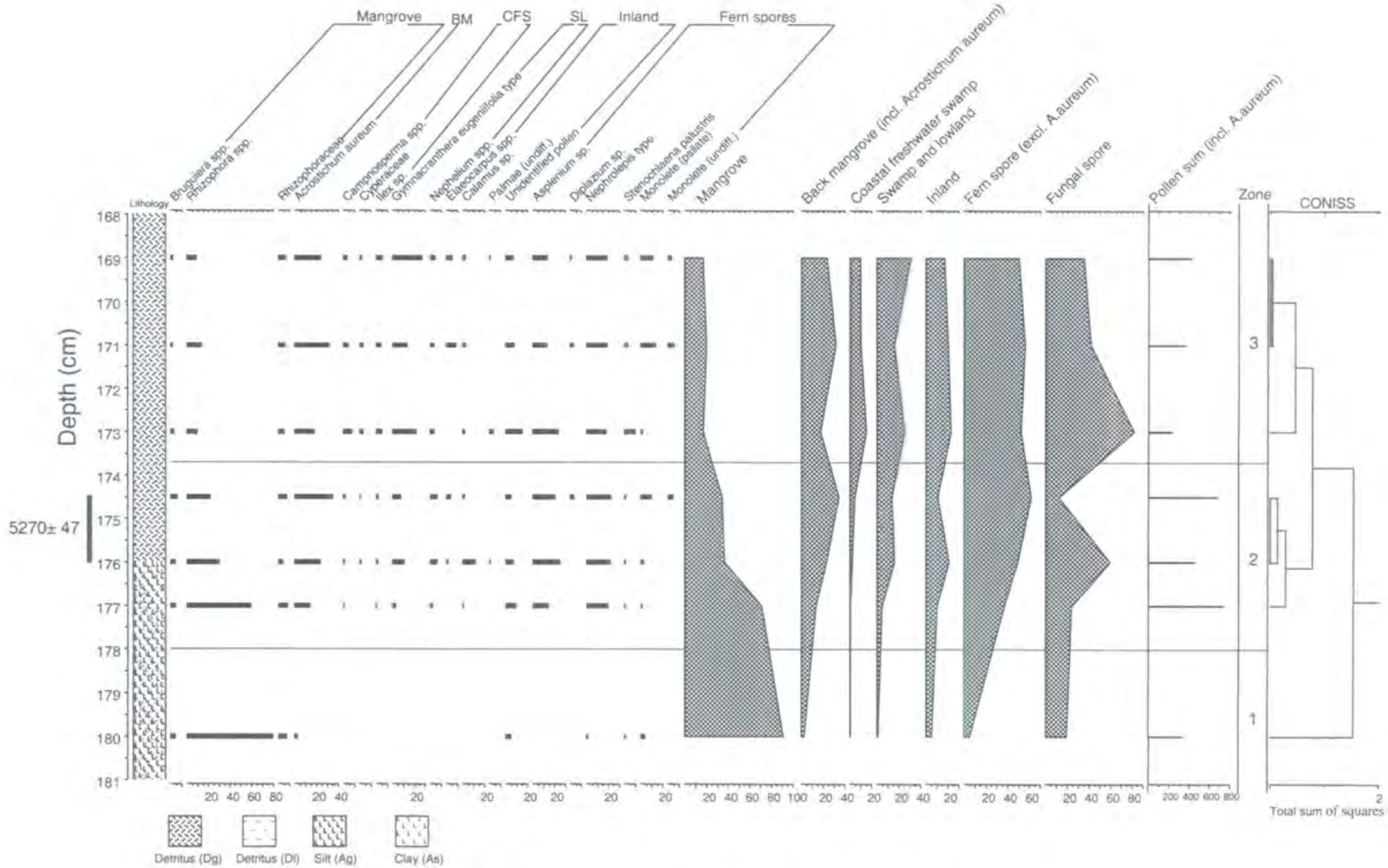


Fig. 6.11 Pollen diagram of core KEC8, Mardi, Kelang.

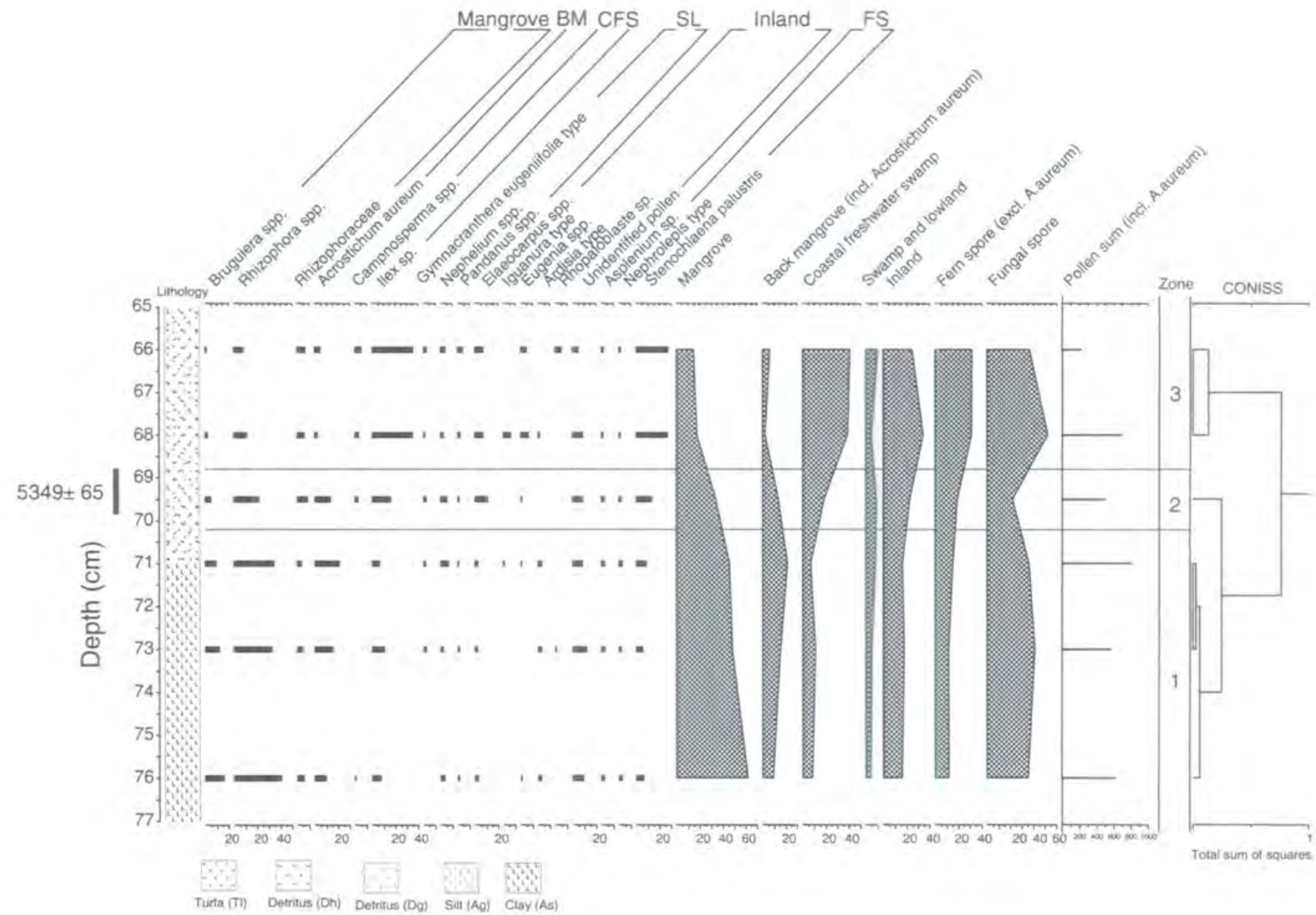


Fig. 6.12 Pollen diagram of core KEC7, Mardi, Kelang.

back mangrove frequencies are low, with the maximum frequencies for the coastal freshwater swamp (39-41%), inland (25-35%), and the fern and fungal spores.

6.5.2.4 Core KEC13

Figure 6.13 shows the pollen diagram of KEC13. Three pollen zones, 1-3, are identified. The zone 3 samples are rather poor in pollen. The sample at 89 and 91 cm depths produced, respectively pollen sums of 136 and 39 grains from 4 and 2 slides analysed. The former sample is nonetheless included in the pollen diagram but the latter is however excluded since the pollen sum is too low.

Zone 1 is dominated by mangrove, forming 74-80% of the pollen sum. In zone 2, high mangrove presence (52-77%) is still maintained. The back mangrove component shows a slight increase value. At the base of zone 2, a peak in swamp and lowland assemblage (38%) is shown, which is due to mainly *Pandanus* spp. Zone 3 shows a low mangrove value (13%), but peak in back mangrove (55%) and the fern and fungal spores.

6.5.3 Penor Transect

In the Kuantan study area, the Penor (north) and Penor (south) transects were investigated (Figs. 5.11, 5.21 & 5.22). As indicated in Chapter 5, biostratigraphic information from this part of peninsula Malaysia is quite unknown. It is for the reason that in both the Penor transects only one core was studied. The analysis also forms an experimental test of the sea level research methodology to be applied in the area.

In the Penor (north) transect, a total of 11 samples was analysed from core KUC15 (Table 6.7). The result is presented as a pollen diagram, shown in Fig. 6.14. Similarly, for the Penor (south) transect, only one core, KUC12, was investigated. Six samples were analysed (Table 6.7), the pollen diagram presented in Fig. 6.15.

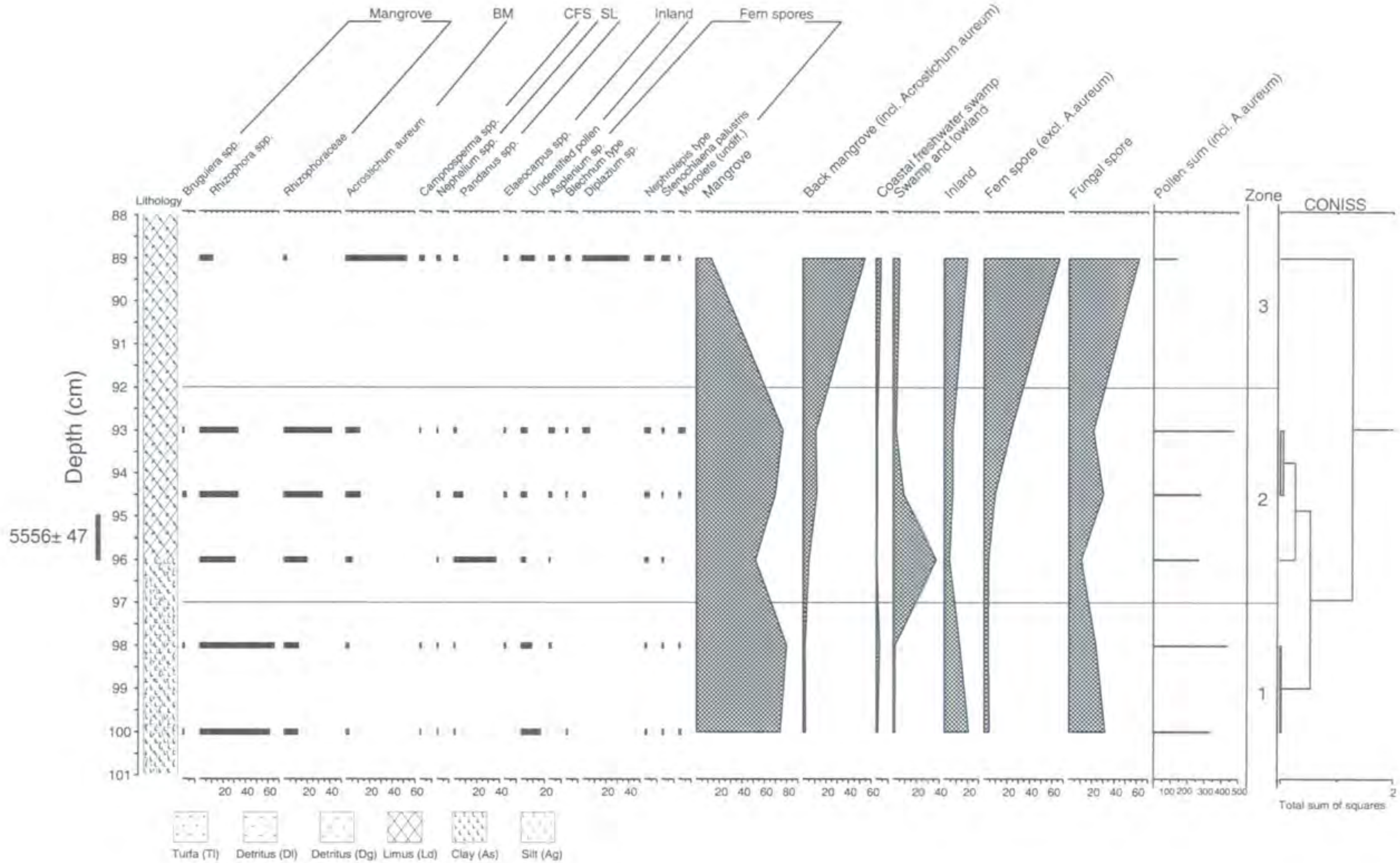


Fig. 6.13 Pollen diagram of core KEC13, Mardi, Kelang.

6.5.3.1 Core KUC15, Penor (north)

In KUC15, three lithologic sequences are differentiated, aside the top secondary infilled layer (Fig. 5.21 and Appendix 1.18). The bottom mottled stiff clay layer (from 275 cm depth) is overlain by the humic to peaty and clayey silt (45-275 cm depth) and capped by thin layer of silty and clayey peat, from 20-45 cm depth. The middle layer shows variations in colour throughout its sequence, from yellowish grey to yellowish brown and brownish black, from the lower to upper section. The boundary between the middle and lower layer being diffuse, while the top and middle layer conspicuous. From the lithology it was decided that analyses should be performed within the boundary of the top silty and clayey peat and the underlying layer. The samples selected are as shown in Table 6.7. The relevance of the Penor (north) site in the study is indicated by its pollen results below.

Table 6.7. Analysed pollen sample levels at Penor, Kuantan.

Penor (north) transect		Penor (south) transect	
Core KUC15		Core KUC12	
Depth (cm)	Altitude (m)	Depth (cm)	Altitude (m)
42	3.094	98	4.705
44	3.074	130	4.385
47	3.044	160	4.085
51	3.004	165	4.035
55	2.964	181	3.875
60	2.914	190	3.785
70	2.814		
80	2.714		
90	2.614		
98	2.534		
105	2.464		

The pollen diagram of KUC15 is divided into four, 1-4, zones (Fig. 6.14). Zone 1 shows predominant mangrove assemblage (77-89%). In the zone, apart from the coastal freshwater swamp (4-12%) and inland (5-10%) assemblages showing their consistent presence, other pollen types are rather insignificant. Zone 2, represented by only one sample (51 cm depth), shows decreasing mangrove and increasing coastal freshwater types. Zone 3, also represented by one sample (47 cm depth), shows a dramatic reduction of the mangrove (19%). The zone is characterised by predominance of the coastal freshwater swamp (78%), which is dominated

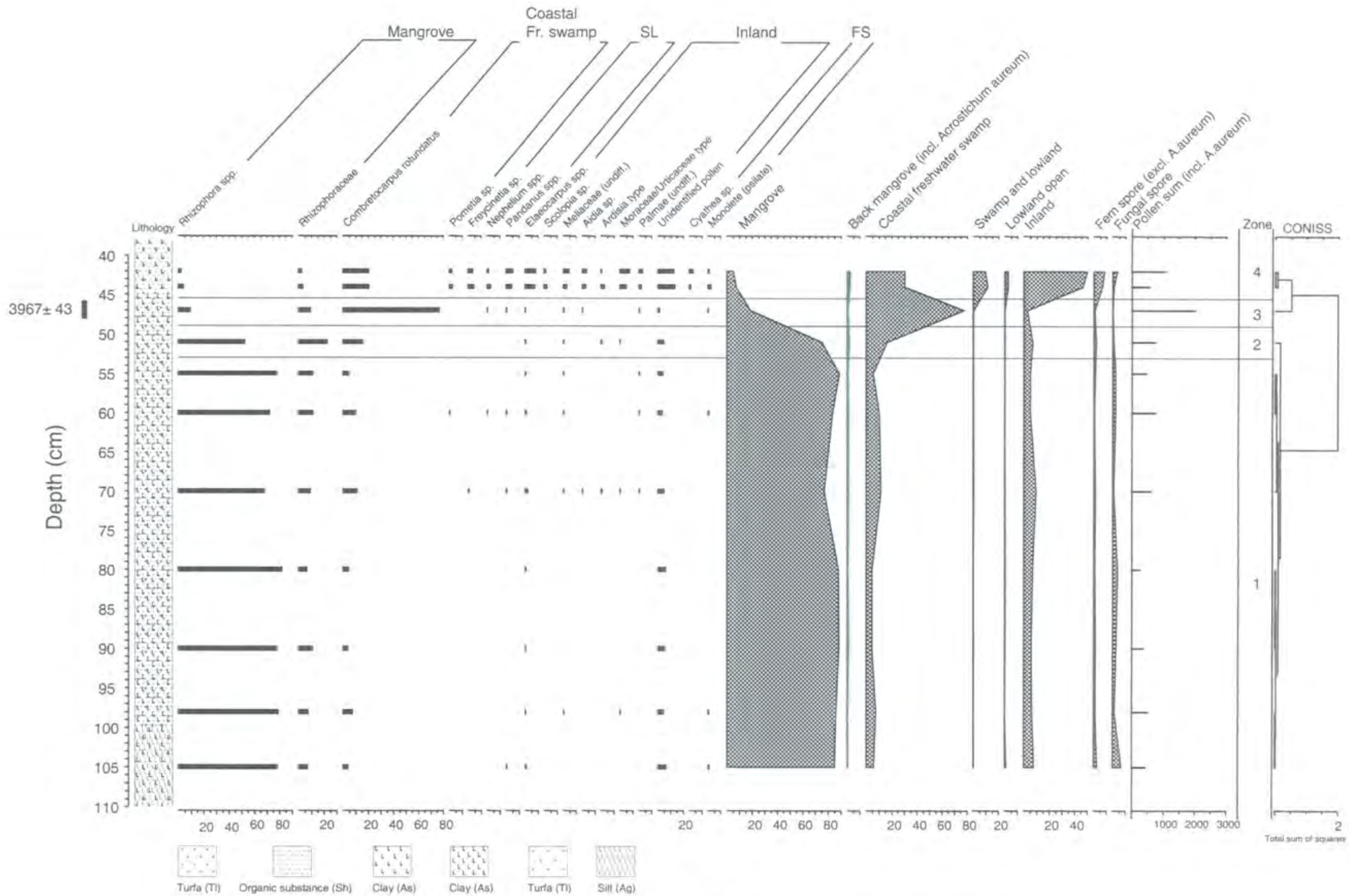


Fig. 6.14 Pollen diagram of core KUC15, Penor (north), Kuantan.

responsible by the specie *Combretocarpus rotundatus*, forming 77% of the pollen sum. Zone 4 shows the domination and increase in species diversity of the inland pollen types. Peak values are shown by the inland (46-50%), swamp and lowland (10-11%), and high value of the coastal freshwater swamp (30%), but low mangrove (5-7%).

6.5.3.2 Core KUC12, Penor (south)

Core KUC12 is made up of four lithologic sequences, apart from the top infilled layer (Fig. 5.22 and Appendix 1.20). Light grey sandy and clayey silt made up the bottom layer. This is overlain by brown to dark brown humic to peaty clayey silt, which is next overlain by black to reddish black peat, and finally capped by yellow to dark brown humic to peaty clay. The contacts between the layers are diffuse (at 227 and 178 cm depths), except between the top peaty clay and lower peat sequence (59 cm depth), which is conspicuous. Samples from peat and the lower layer, between 95-195 cm depths, were selected for analysis (Table 6.7).

Figure 6.15 shows the pollen diagram of KUC12. The diagram was erected to basically present the pollen assemblages of the analysed samples in assessing the suitability of the core for the study. It is however shown that terrestrial pollen types, the inland, swamp and lowland and the coastal freshwater swamp assemblages, predominate throughout the samples. Mangrove type is found to be rather insignificant. It is concluded that the analysed KUC12 core, and by implication the Penor (south) transect, is unsuitable for this study, since the results merely provide a vegetation record of the site. This inference is backed up by other observations. The sampling altitude of the KUC12 core is higher than that of KUC15, which explains the absence of the mangrove sequence displayed in the latter. Mangrove assemblage predominates in KUC15 up to about 3.0 m MSL altitude. It is suggested that in Penor (south), during the deposition of the peat and the lower peaty clayey silt layer, no direct sea influence is present.

6.6 Fossil Diatoms

As indicated earlier, almost all samples prepared for pollen were also analysed at similar levels for diatoms (Appendix 2.2). In the core samples from

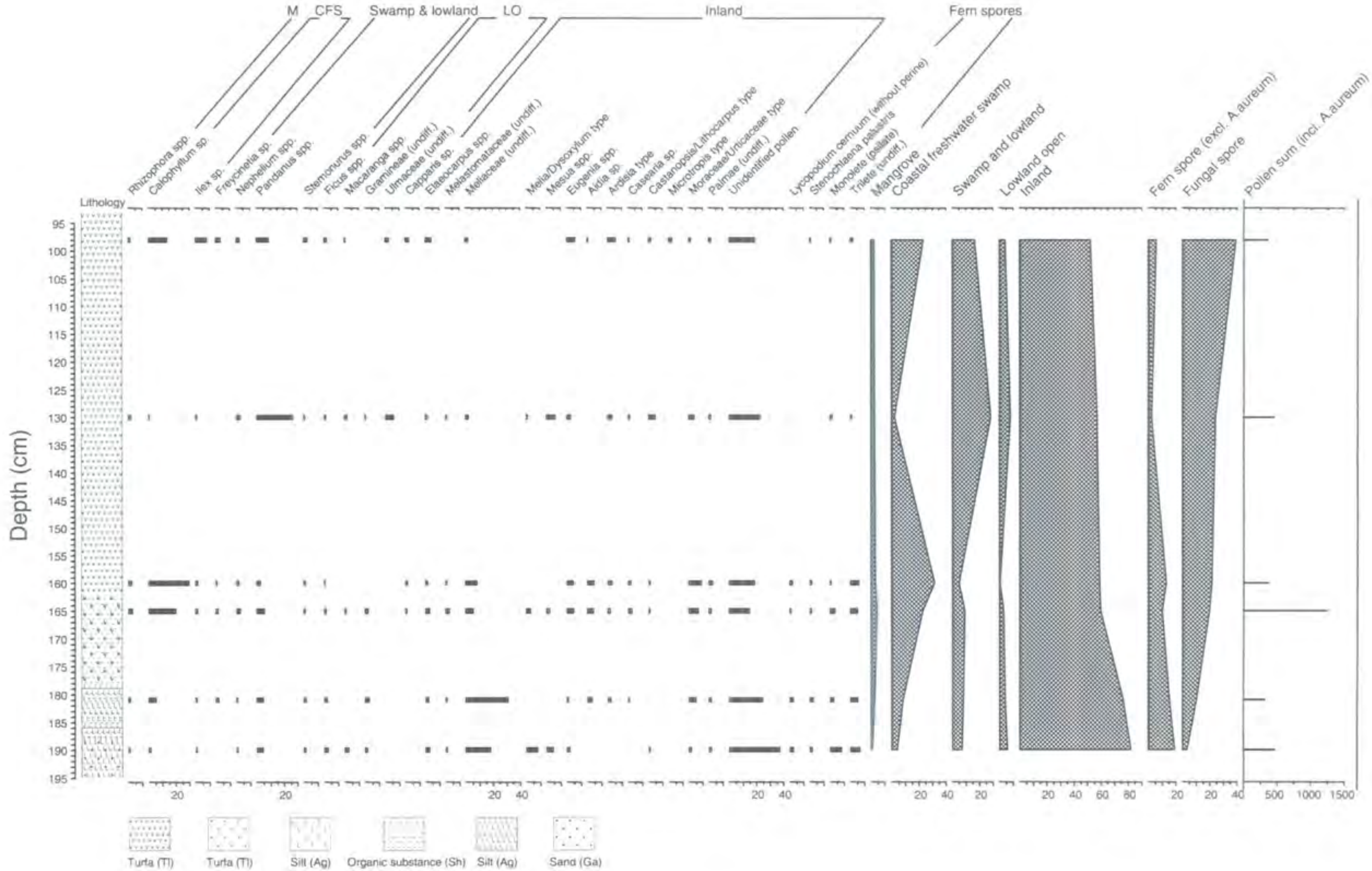


Fig. 6.15 Pollen diagram of core KUC12, Penor (south), Kuantan.

Kelang, only those from the Meru transect, KEC2 and KEC1, showed significant diatom presence (Figs. 6.16 to 6.19). Even so, in the samples analysed, diatom preservation is not as good when compared to the palynomorps. For the Mardi transect (cores KEC9, KEC8, KEC7 and KEC13), diatoms are absent in all the peat sequence and rare to only very few in the lower clayey/silty layer.

In Kuantan samples, core KUC15 indicates a presence of small to moderate amount of diatoms in the clayey peat layer (depths of 42 & 44 cm) but absent in the lower peaty clay sequence (47 cm depth and deeper). For core KUC12, in the horizon similarly analysed for pollen, diatom is either absent or only few are found (Appendix 2.2).

The discussions below thus concentrate only on the cores KEC2 and KEC1.

6.6.1 KEC2

Six samples were processed, as in pollen analysis, within the zone of the core's regressive contact (Table 6.5). The 71, 73 and 76 cm depth levels showed the presence of more than 250 valves from only one slide analysed. For the 68 and 70 cm depths only 45 and 70 valves respectively were counted from two slides analysed. An interesting observation is the number of diatoms counted decreases from the lower grey clayey silt to the upper dark reddish brown peat sequences. At the 66 cm depth only very rare diatoms were found.

Figures 6.16 and 6.17 show the diatom diagrams of KEC2. Two diatom zones, 1 & 2, are distinguished. *Cyclotella striata*, a mesohalobous and planktonic form, constitutes the most abundant diatom species, comprising between 55-100% TDV in all the levels analysed. Thus in both zones 1 & 2, the mesohalobous and the planktonic assemblages are predominant and attain peak values in zone 2. The polyhalobous diatoms show decreasing values from zone 1 to 2, from 35-7%, and are absent at 68 cm. The epipelic group, which overall has low frequencies, shows its peak in zone 2 (10%). Table 6.8 shows the relative comparison of the microfossil zones, which clearly defines zones 1 & 2 of both the pollen and diatom analyses.

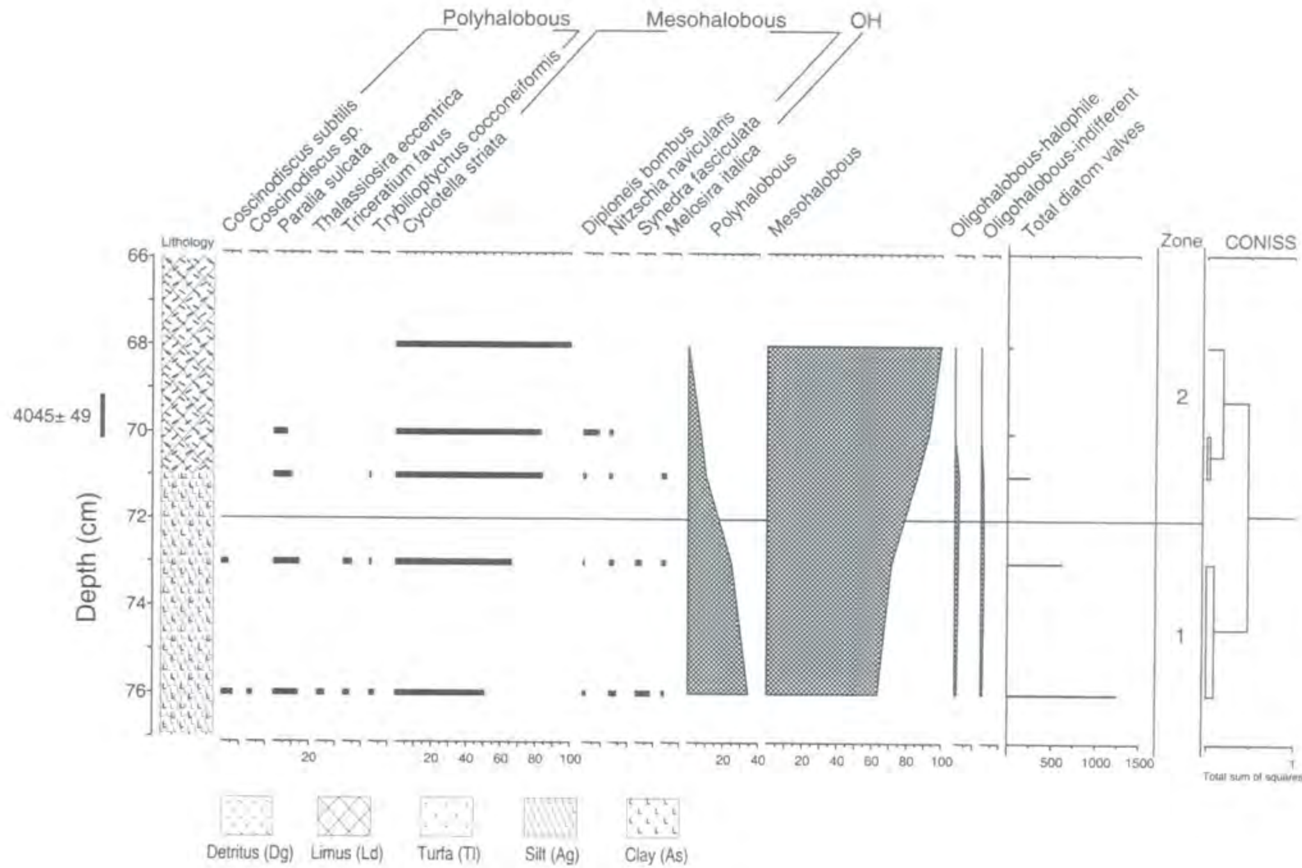


Fig. 6.16 Diatom diagram (salinity) of core KEC2, Meru, Kelang.

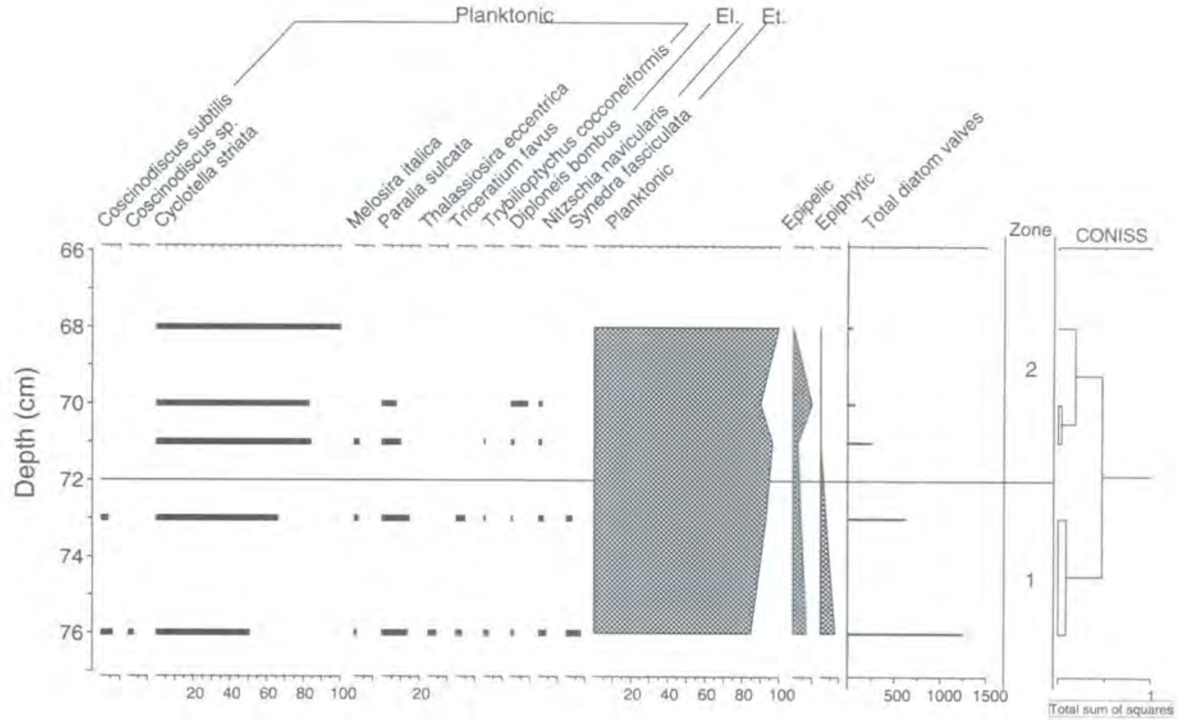


Fig. 6.17 Diatom diagram (life form) of KEC2, Meru, Kelang.

6.6.2 KEC1

The six samples processed in KEC1 generally show low to moderate diatom preservation. Diatoms are found in the lower three levels, all in the yellowish grey to grey sandy and clayey silt. Diatoms are rare or absent in the upper three samples, 105, 107 and 109 cm, in the dark reddish brown peat. Sample 111 cm recorded only 54 valves from 2 slides, while in 113 and 116 cm 153 and 105 valves respectively are counted from 3 slides each. In addition to the low counts, only 6 species are identified (Appendix 5.14).

Table 6.8. Relation of pollen and diatom zones in core KEC2.

Sample depth (cm)	Altitude (m)	Pollen zone	Diatom zone
66	4.243	3	- (rare)
68	4.223	2	2
70	4.203	2	2
71	4.193	2	2
73	4.173	1	1
76	4.143	1	1

Figures 6.18 and 6.19 show the diatom diagrams of KEC1, divided into 2 zones. As in KEC2, *Cyclotella striata*, a mesohalobous and planktonic form, constitutes the most abundant diatom species in all the three samples, comprising between 59% and 84% TDV. Thus the mesohalobous and planktonic diatoms predominate in zones 1 and 2. In zone 2 the polyhalobous group is absent and the mesohalobous taxa at 100%, the epipelic group shows its peak (41%) while the planktonic forms are reduced.

Table 6.9. Relation of pollen and diatom zones in core KEC1.

Sample depth (cm)	Altitude (m)	Pollen zone	Diatom zone
105	4.354	3	- (nil)
107	4.334	3	- (rare)
109	4.314	2	- (nil)
111	4.294	2	2
113	4.274	1	1
116	4.244	1	1

Table 6.9 shows the relation of the microfossil zones of core KEC1. Zone 1 of both the pollen and diatom records coincides. Due to the absence of diatoms in the peat samples, diatom analysis is rendered less effective compared to pollen where three pollen zones can be distinguished.

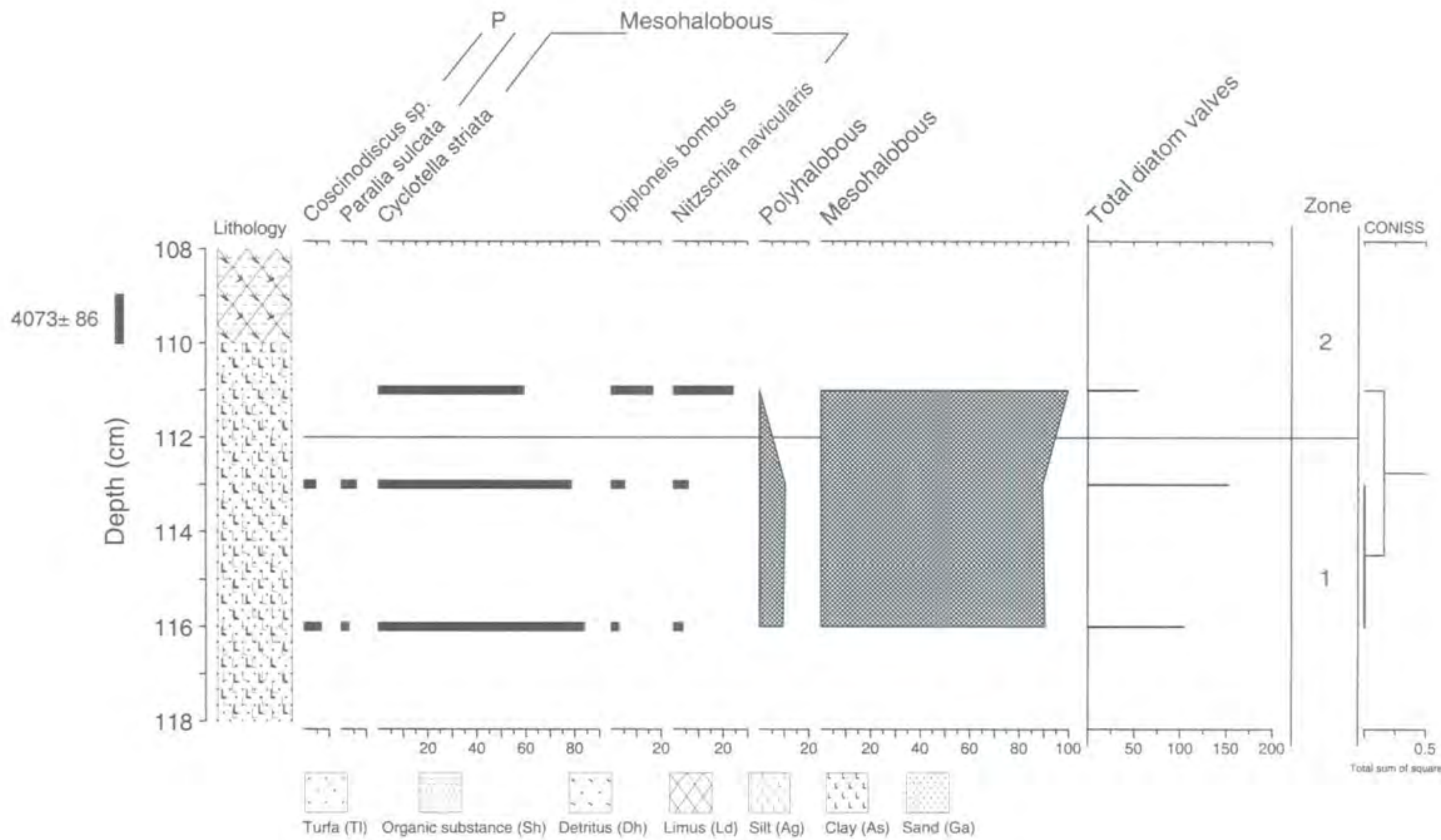


Fig. 6.18 Diatom diagram (salinity) of core KEC1, Meru, Kelang.

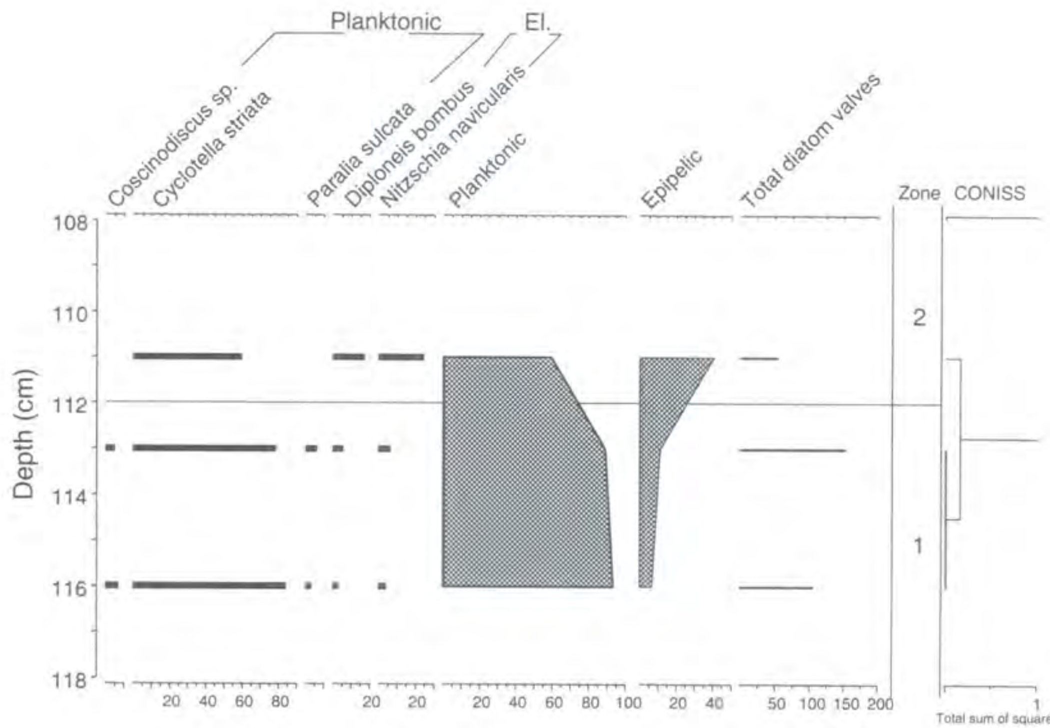


Fig. 6.19 Diatom diagram (life form) of core KEC1, Meru, Kelang.

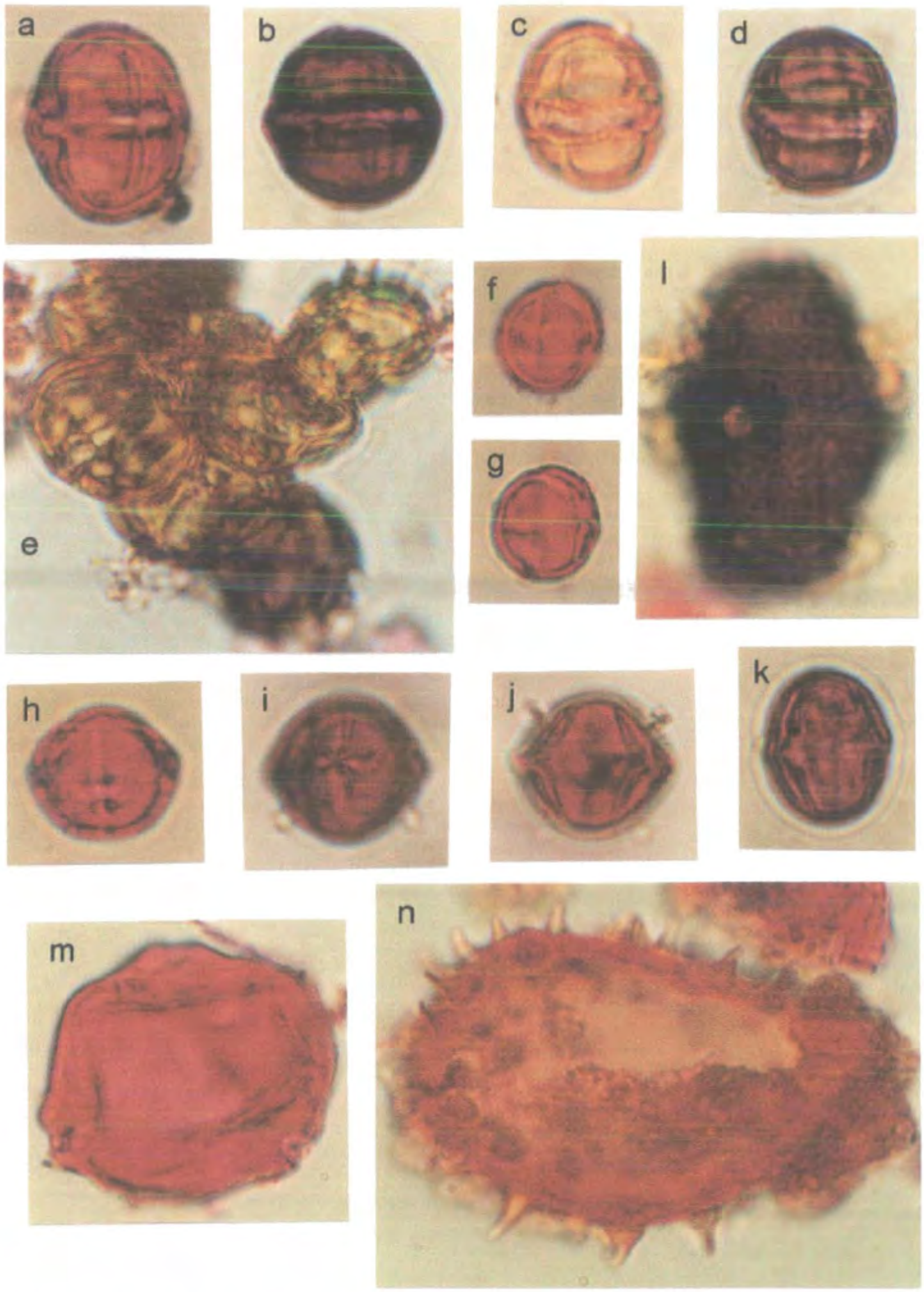


Fig. 6.20 Pollen grains from Kelang and Kuantan. All is from core samples, except (a) & (m) are surface samples. (a-d) *Rhizophora* spp.; (e) *Rhizophora* cluster; (f-g) *Bruguiera* sp.; (h-k) Rhizophoraceae undiff.; (l) *Sonneratia caseolaris*; (m) *Casuarina equisetifolia*; (n) *Nypa fruticans*.
All photographs taken at 1000x magnification.

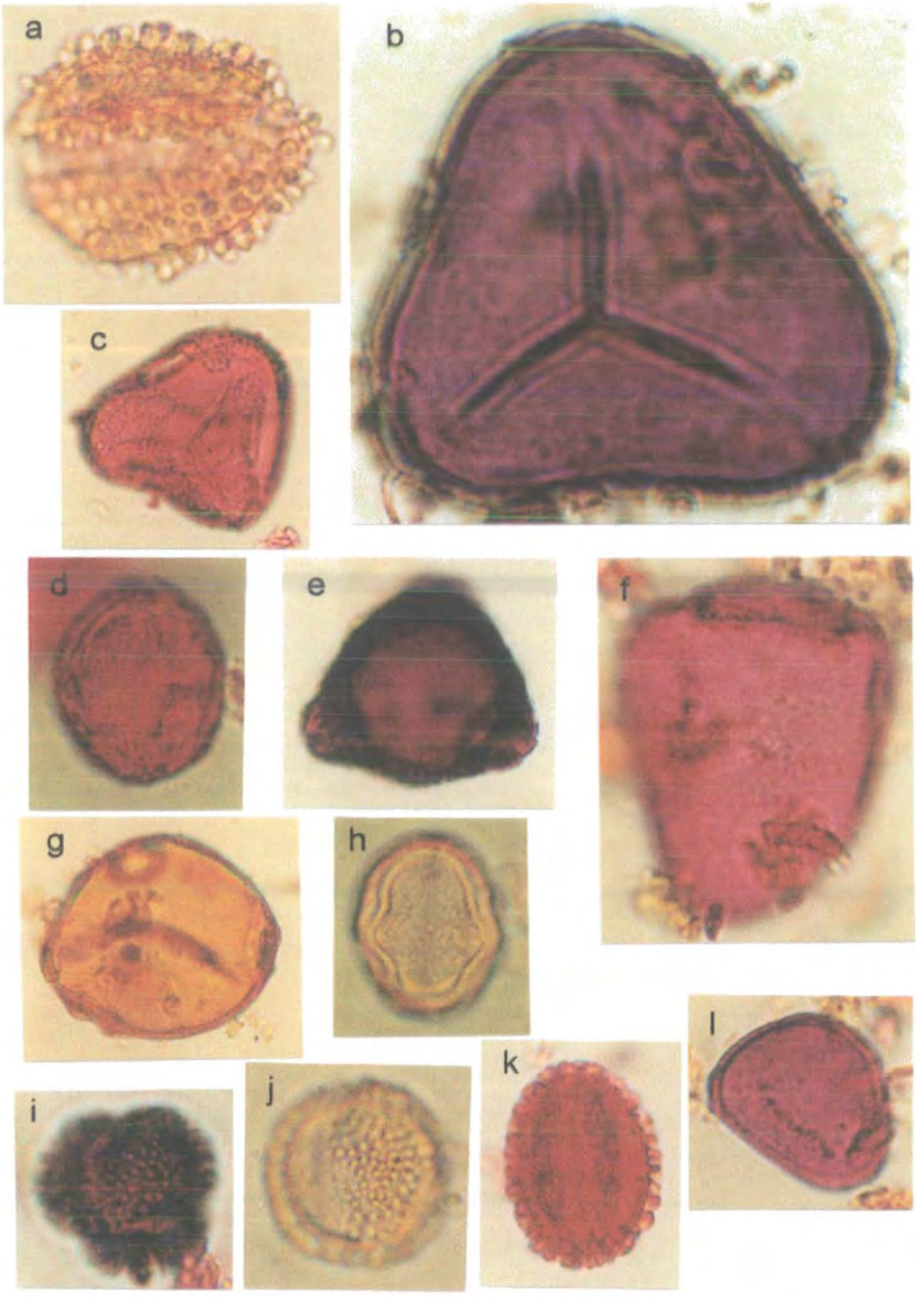


Fig. 6.21 Pollen grains from Kelang and Kuantan core samples.
(a) *Oncosperma tigillarium*; (b-c) *Acrostichum aureum*; (d) *Campnosperma* sp.; (e) *Garcinia* sp.; (f) Cyperaceae undiff.; (g) *Durio* sp.; (h) *Combretocarpus rotundatus*; (i-k) *Ilex* spp.; (l) *Gymnacranthera eugeniifolia* type.
All photographs taken at 1000x magnification, except (c) at 400x.

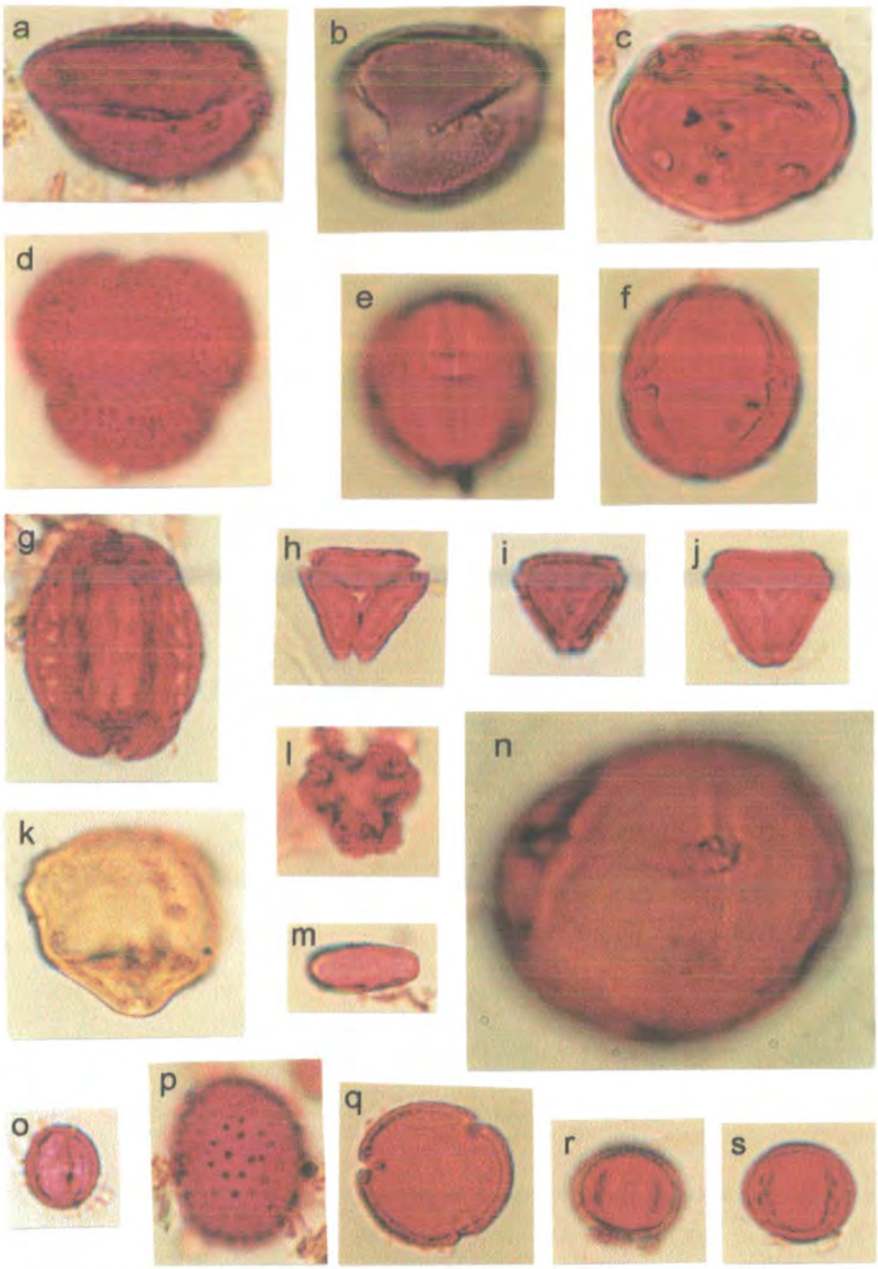


Fig. 6.22 Pollen grains from Kelang and Kuantan core samples.
(a) *Iguanura* type; (b) *Calamus* sp.; (c) Malpighiaceae undiff.;
(d) Dipterocarpaceae undiff.; (e-f) *Casearia* sp.; (g) *Barringtonia* sp.;
(h-j) *Eugenia type* ; (k) *Myrica* sp.; (l) Melastomataceae undiff.;
(m) *Ficus* sp.; (n) Meliaceae undiff.; (o) *Elaeocarpus* type;
(p) *Pandanus* sp.; (q) *Stemonurus* sp.; (r-s) *Nephelium* sp.
All photographs taken at 1000x magnification.

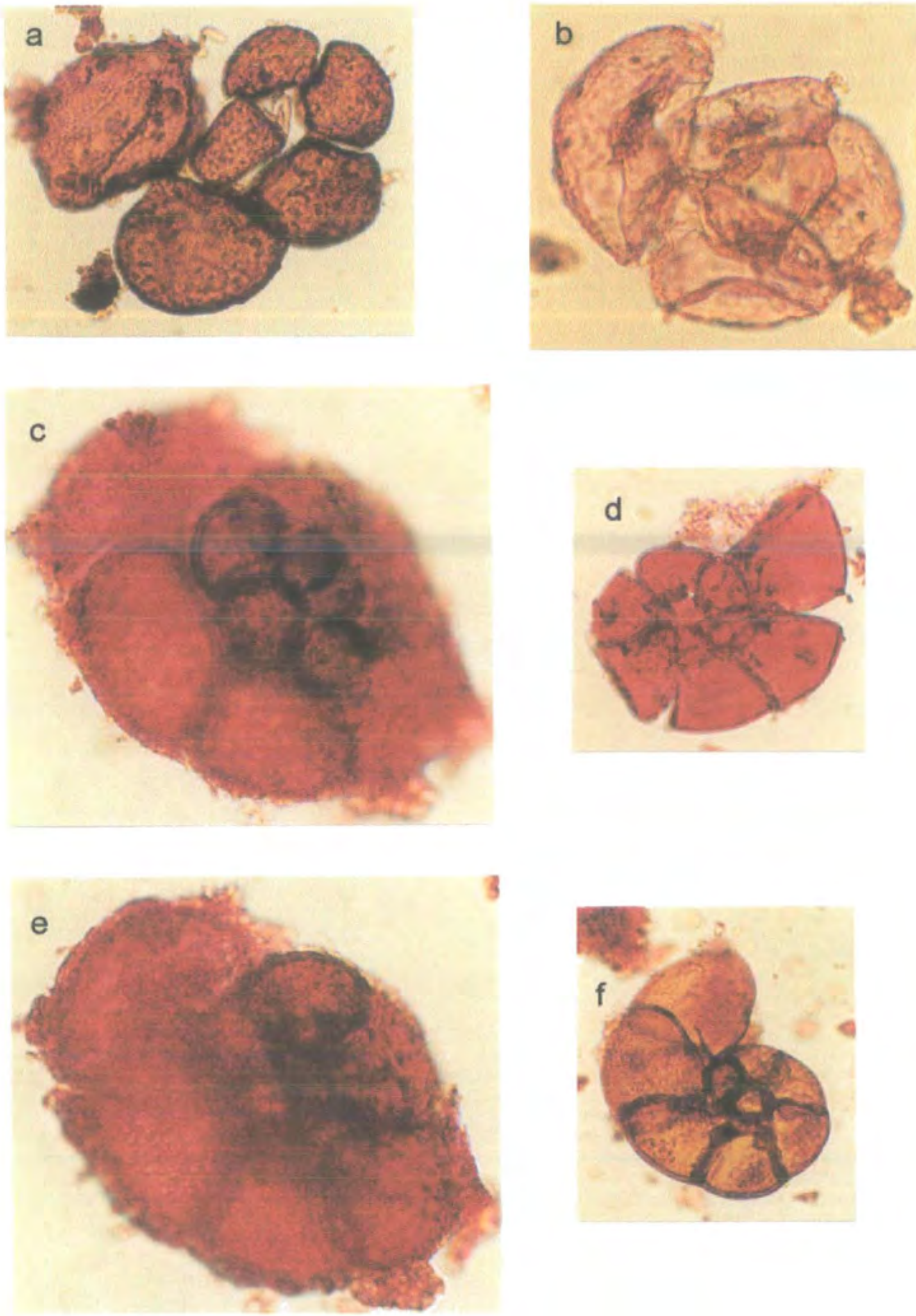


Fig. 6.23 Foraminifera inner lining in pollen preparation from Kelang core samples. All photographs taken at 400x magnification, except (a) & (f) at 200x.

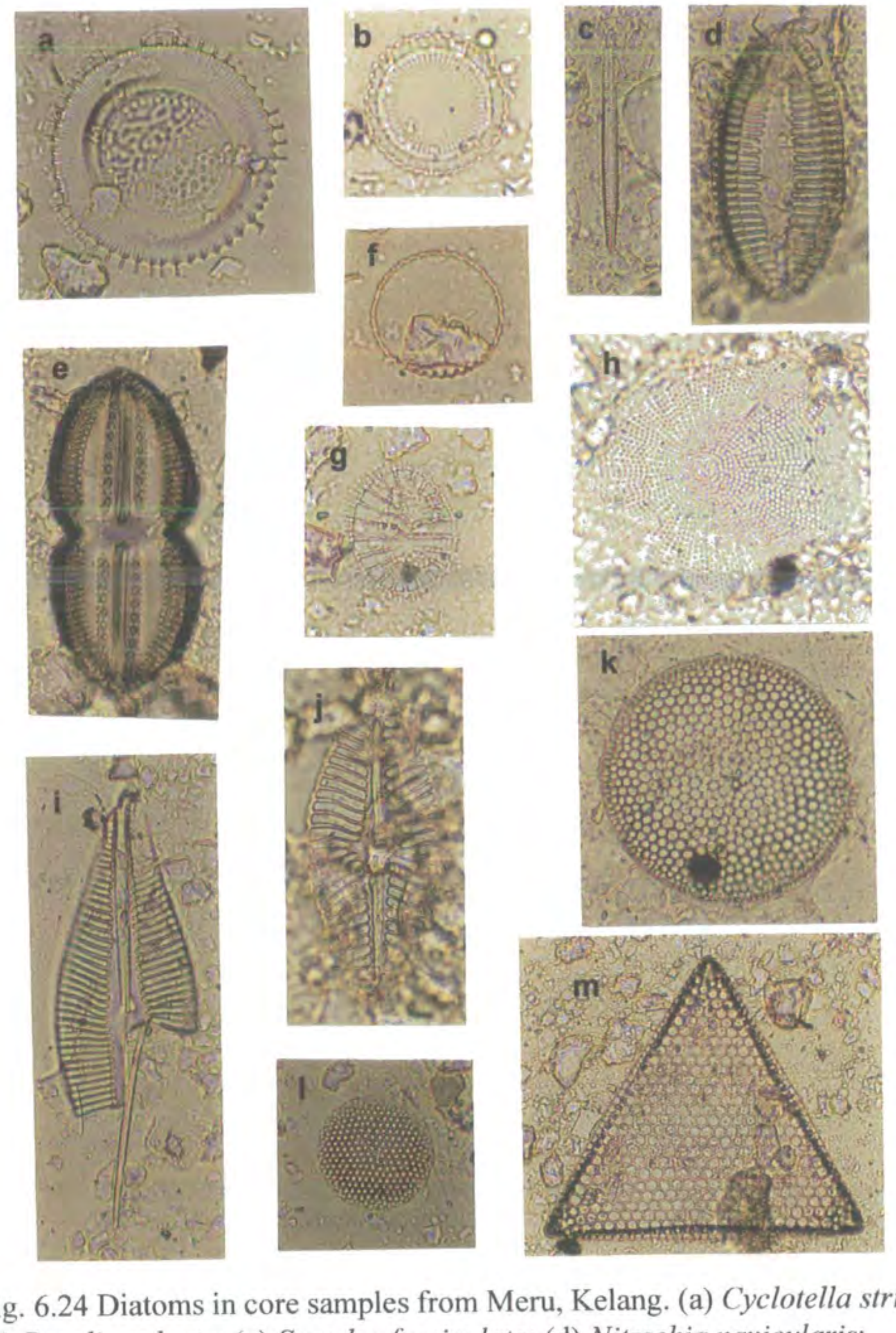


Fig. 6.24 Diatoms in core samples from Meru, Kelang. (a) *Cyclotella striata*; (b) *Paralia sulcata*; (c) *Synedra fasciculata*; (d) *Nitzschia navicularis*; (e) *Diploneis bombus*; (f) *Melosira italica*; (g) *Trybilioptychus cocconeiformis*; (h) *Coscinodiscus subtilis*; (i) *Navicula rhynchocephala*; (j) *Navicula* sp.; (k) *Coscinodiscus radiatus*; (l) *Thalassiosira eccentrica*; (m) *Triceratium favus*. All photographs taken at 400x magnification, except (m) at 200x.

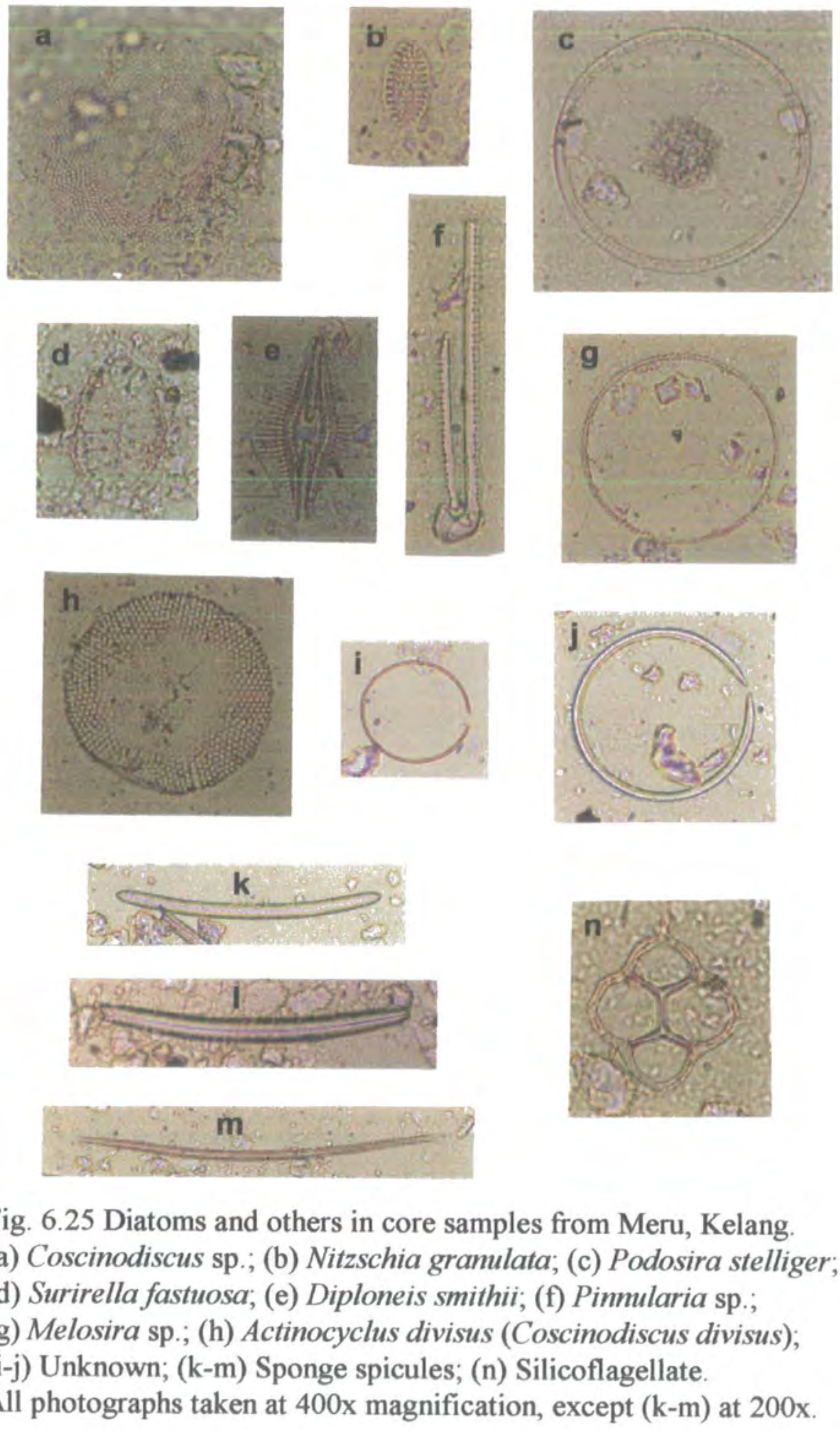


Fig. 6.25 Diatoms and others in core samples from Meru, Kelang.
(a) *Coscinodiscus* sp.; (b) *Nitzschia granulata*; (c) *Podosira stelliger*;
(d) *Surirella fastuosa*; (e) *Diploneis smithii*; (f) *Pinnularia* sp.;
(g) *Melosira* sp.; (h) *Actinocyclus divisus* (*Coscinodiscus divisus*);
(i-j) Unknown; (k-m) Sponge spicules; (n) Silicoflagellate.
All photographs taken at 400x magnification, except (k-m) at 200x.

CHAPTER 7

POLLEN AND DIATOM ASSEMBLAGES AS SEA LEVEL INDICATORS

7.1 Introduction

The pollen and diatom analytical results of both the contemporary and fossil samples reveal their significance in sea level investigations. Pollen analysis in particular, is found to be the more applicable method in the study area. The contemporary results of both analyses however, provide useful data for the pollen and diatom assemblages of the respective sites. Together the pollen and diatom data corroborate and substantiate the interpretation. They show information relating to factors such as inundation and reference water levels. Contemporary assemblages are important in establishing the indicative range of the fossil sea level indicator. Determination of the indicative meaning of the fossil sea level indicator, or the sea level index (SLI) point is discussed below.

Figures 7.1 to 7.4 and Tables 7.1 to 7.2 summarise the microfossil characteristics in relation to other associated environmental variables. Figures 7.2 and 7.4 represent taxa exceeding 5% of the respective pollen sum and TDV.

7.2 Contemporary pollen and diatom assemblages

The contemporary pollen and diatom results show significant changes in their assemblages with altitude. The distribution of the microfossil assemblages is observed to correlate to a local reference water level, with certain assemblages associated with and therefore characterising a particular tidal zone. In this study, pollen and diatom associations from about MLWS to the supratidal are distinguished. In pollen analysis, the main assemblages, the mangrove, back mangrove, coastal freshwater swamp and the inland grouping (including swamp and lowland, lowland open and the inland), are found to be of prime importance. For diatom analysis the halobian and life form classifications provide significant correlations. Both pollen and diatoms contribute help to define the indicative meaning and interpretation of the local environment at the contemporary sites.

7.2.1 Kelang contemporary data

The combined pollen and diatom results of their respective assemblages and taxa are shown in Figs. 7.1 and 7.2. The microfossil distribution is related to the reference water levels ranging from about MSL to MHWS tides. Table 7.1 summarises the pollen and diatom characteristics.

Pollen zone A, typified by abundant mangrove and low back mangrove assemblages, correlates well with tidal levels from about MSL to MHWN (Fig. 7.1; Table 7.1). This is also depicted approximately by diatom zone A, exemplified by a predominance of polyhalobous and planktic taxa with significant mesohalobous types. The microfossil assemblages of zone A reflect a significant marine input. The frequency of daily tidal inundation, which ranges from 54-27% (Anon, 1996) indicates that the zone is submerged by the sea for a duration of about 6-12 hours per day.

Pollen zone C is generally characterised by a reduction in mangrove, abundant back mangrove and a significant increase in the coastal freshwater swamp assemblages. It should be noted that the respective mangrove and back mangrove assemblages of *Rhizophora* spp. and *Oncosperma tigillarium,* are contrastingly represented in the tidal mangrove swamp and *Nypa* vegetation transects. The predominance of the back mangrove in zone C is mainly ascribed to *Oncosperma tigillarium* from the *Nypa* transect, which at the same time shows a very low mangrove value. The quite significant presence of the mangrove assemblage in zone C is indicated by samples from the tidal mangrove swamp transect, in which similar samples show a low back mangrove trend, except in KES17. Pollen zone C approximates to the upper half of the MHWN to MHWS range. Within the tidal frame, frequency of daily inundation is less than 14%.

Pollen zone D, identified only by one sample (KES18), shows low mangrove and back mangrove taxa and predominated by the inlands inclusive types. It is approximately related to MHWS tide, with daily inundation of only about 2-1%.

Pollen zones C and D coincide with diatom zone C. The latter contrasts greatly with diatom zone A, with dominant mesohalobous and episammic taxa and a significant presence of the tychoplantics. The diatom assemblages of zone C reflect a brackish environment.

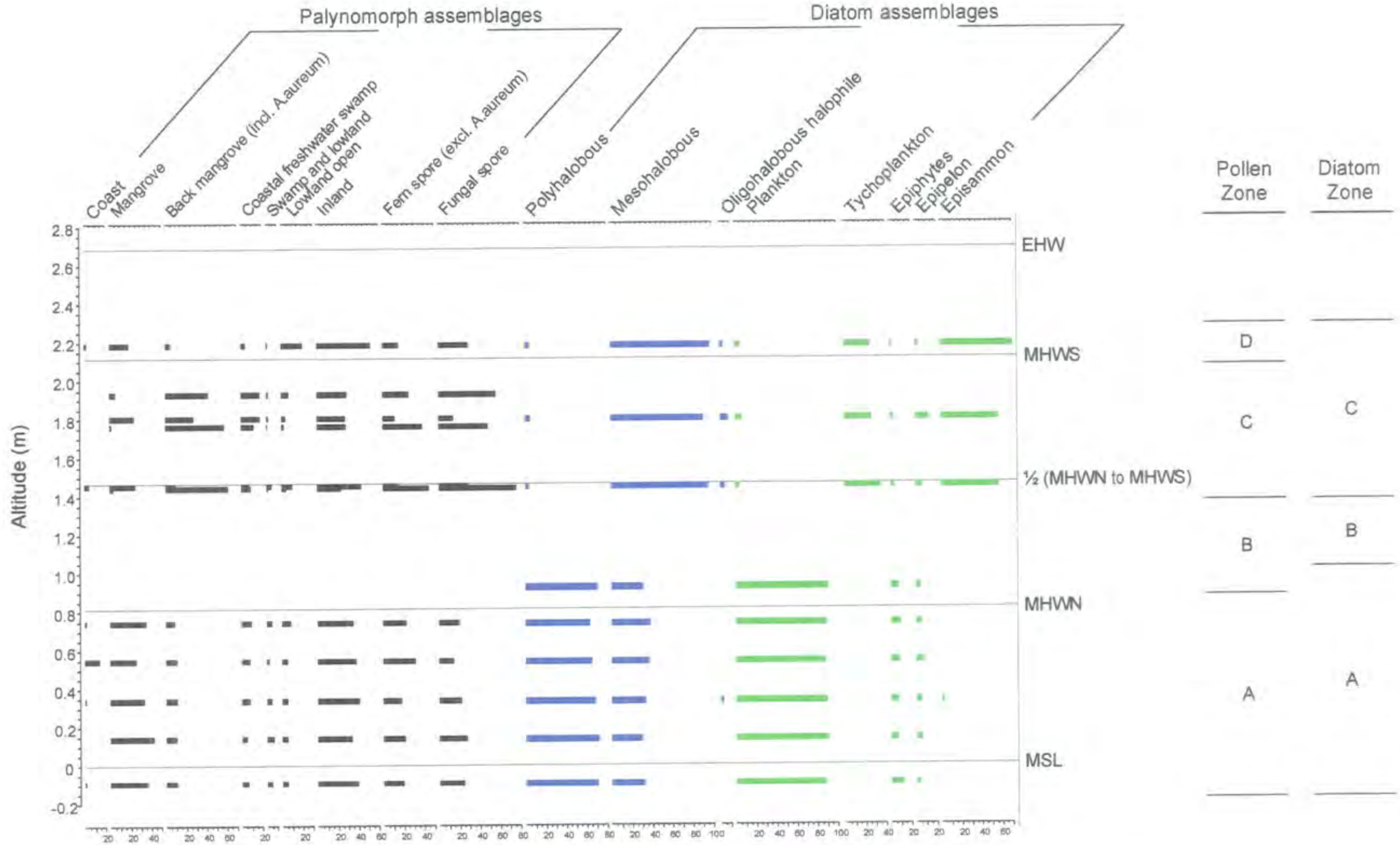


Fig. 7.1 Vertical distribution and zonation of contemporary pollen and diatom assemblages, in Kelang.

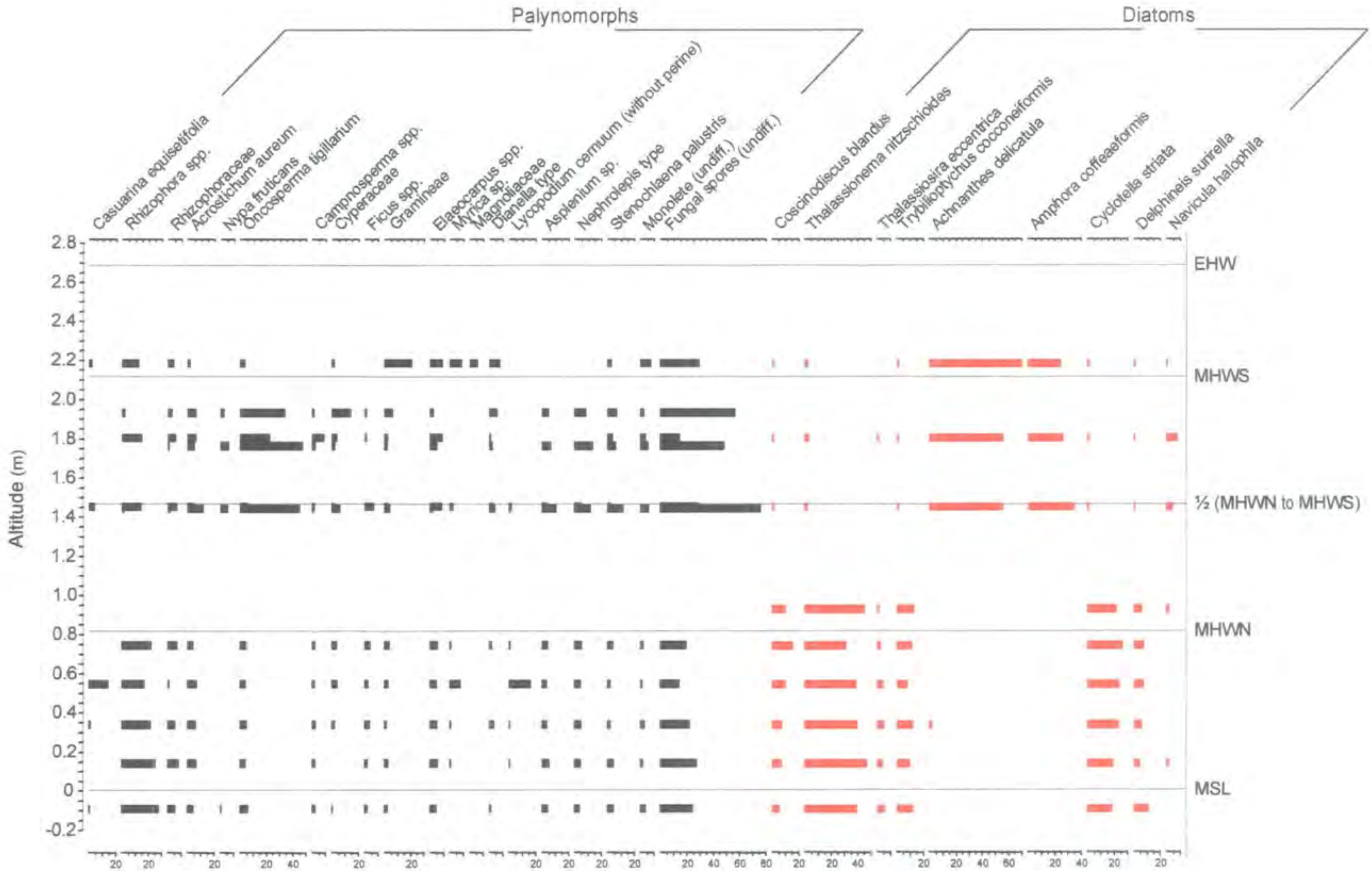


Fig. 7.2 Plot of contemporary pollen and diatom taxa (>5%), from Kelang.

Table 7.1. Summary of altitude, vegetation, frequency of tidal inundation, pollen and diatom characteristics from the Kelang contemporary sites.

Sample no.	Altitude (m)	Vegetation	Frequency (%) daily inundation	Pollen characteristic	Diatom characteristic
	2.683	EHW (of Dec. 1996)			
KES18	2.181	Embankment side	~1	High Gramineae (20%). Predominant inland taxa (52%). Reduced mangrove and back mangrove. Pollen zone D. Correlates approx. to MHWS tidal level.	Predominant *Acnanthes delicatula;* abundant *Amphora coffeaeformis*. Mesohalobous and episammic taxa predominate; tychoplanktics significant. Diatom zone C. Correlates to a reference water level at about the upper half of MHWN to MHWS tidal range.
	2.113	MHWS	1-2		
KES21	1.927	*Nypa* vegetation	3-4	Abundant *Oncosperma tigillarium*. Predominant back mangrove (up to 62%). Decrease mangrove. Fern and fungal spores abound. Pollen zone C. Correlates approx. to the upper half of MHWN to MHWS tidal range.	
KES17	1.801	Mangrove tidal swamp	5-6		
KES19	1.759	*Nypa* vegetation	6-7		
	1.463	Mid of MHWN to MHWS	12-13		
KES16	1.449	Mangrove tidal swamp	12-14		
KES20	1.439	*Nypa* vegetation	12-14		
KES15	0.926	Mangrove tidal swamp	27-28	Few pollen grains.	Predominant *Thalassionema nitzschioides*; abundant *Cyclotella striata*; significant *Trybilioptychus cocconeiformis*, *Coscinodiscus blandus* and *Delphineis surirella*. Polyhalobous and planktic taxa predominate. Mesohalobous taxa well represented. Diatom zone A. Correlates to about MSL to MHWN range.
	0.813	MHWN	29-31	Predominant *Rhizophora* spp. Highest mangrove proportion (25-42%). Low back mangrove (8-10%). High inland taxa (33-39%). Pollen zone A. Correlates to a reference water level at about MSL to MHWN range.	
KES13	0.740	Mangrove tidal swamp	32-33		
KES11	0.542	Mangrove tidal swamp starts	38-39		
KES9	0.335	Unvegetated tidal flat	43-45		
KES7	0.138	Unvegetated tidal flat	48-50		
	0	MSL	51-52		
KES3	-0.095	Unvegetated tidal flat	53-54		

7.2.2 Kuantan contemporary data

Figures 7.3 and 7.4 show the combined pollen and diatom frequency diagrams of the Kuantan contemporary, for both their assemblages and taxa respectively. A relationship between the microfossil zones and local reference water level from about MLWS to the supratidal zone is indicated. A summary of the contemporary pollen and diatom characteristics and association is presented in Table 7.2.

Pollen zone A, characterised by predominant mangrove (up to 67%), low back mangrove and the continuous presence of the coastal freshwater swamp

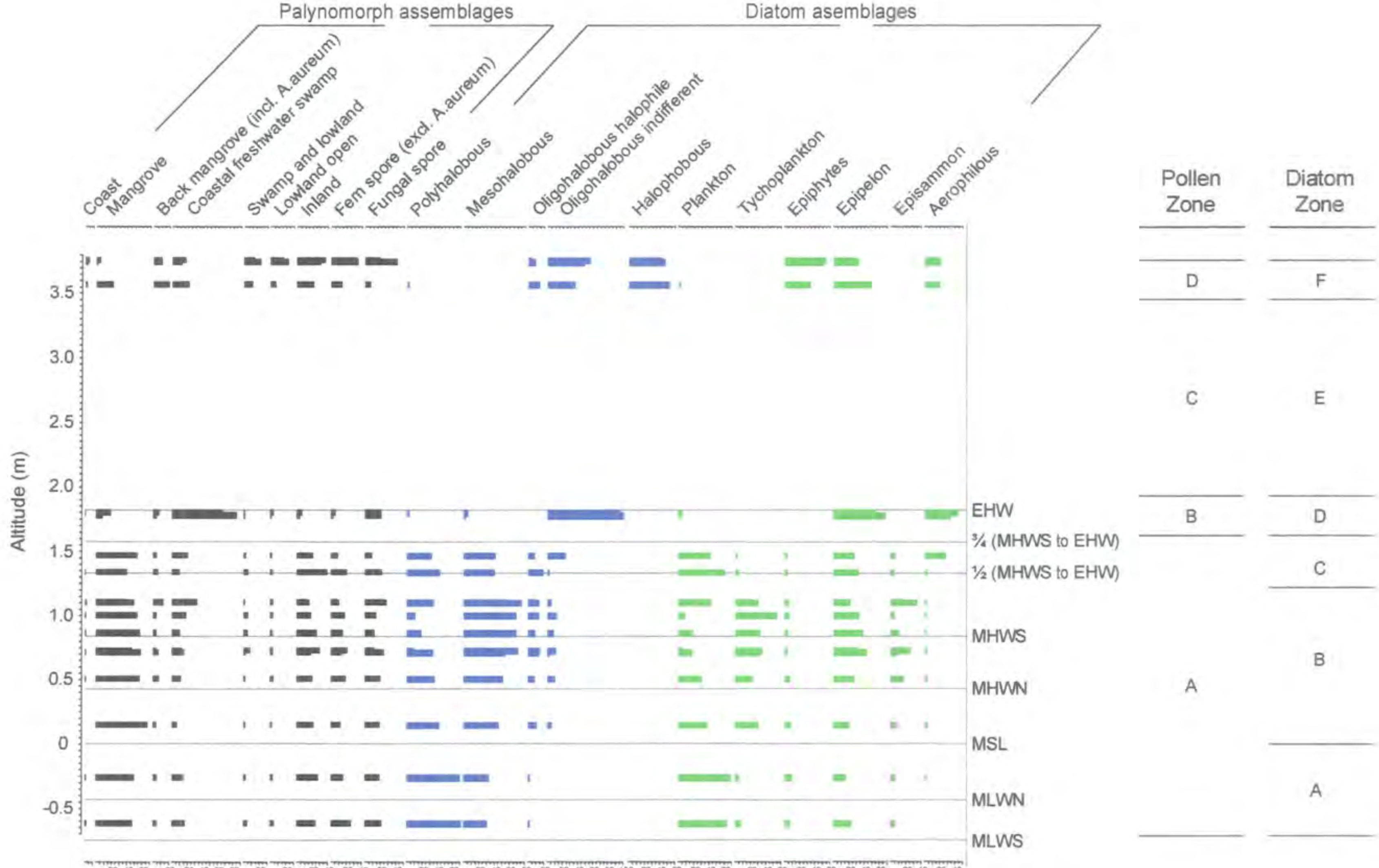


Fig. 7.3 Vertical distribution and zonation of contemporary pollen and diatom assemblages, in Kuantan.

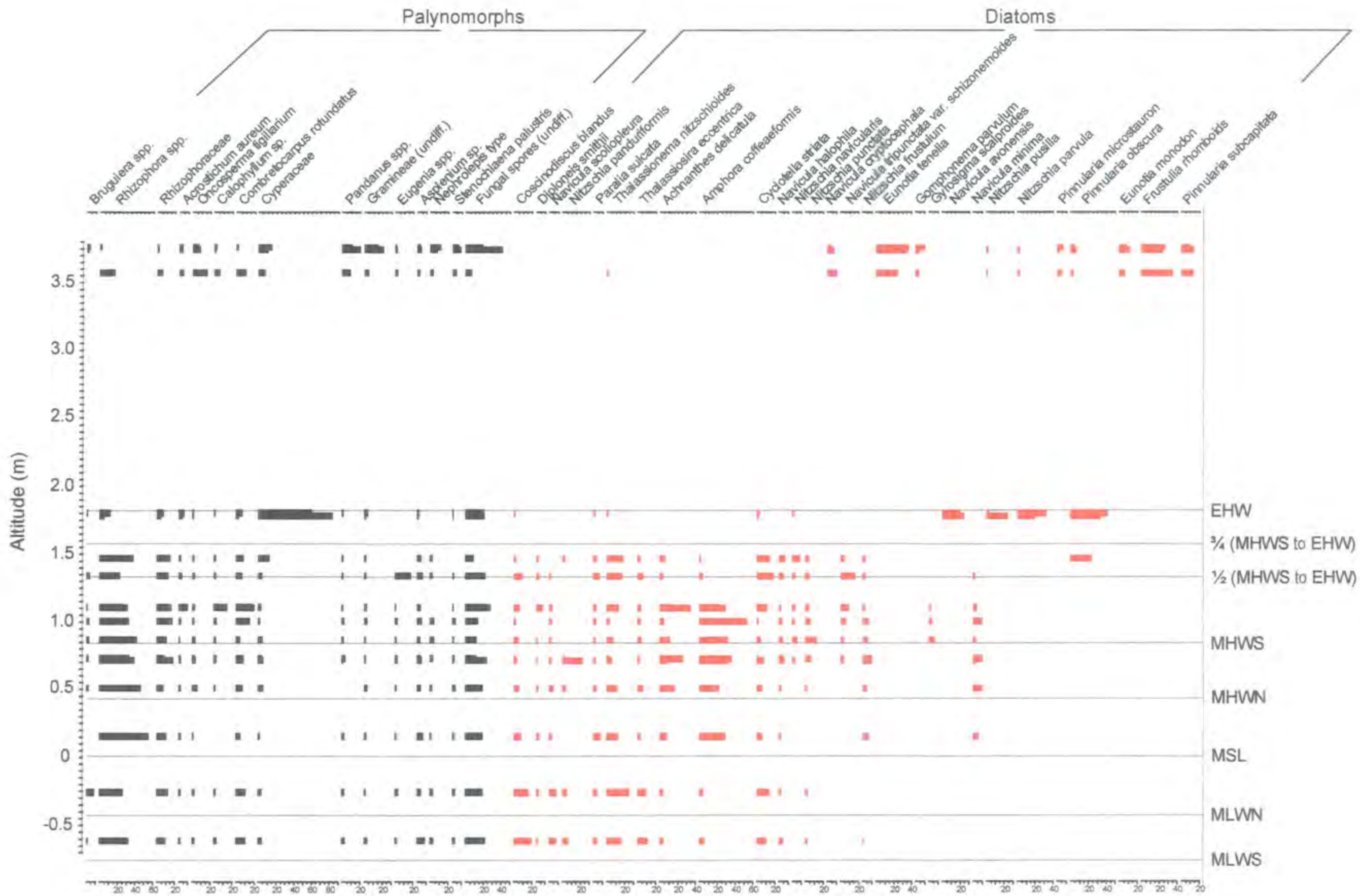


Fig. 7.4 Plot of contemporary pollen and diatom taxa (>5%), from Kuantan.

assemblage, typifies the tidal frame from MLWS to about ¾(MHWS to EHW) levels. This covers almost the whole interval of the tidal zone, where the frequency of daily inundation ranges from 90-0.3%. Better differentiation is achieved by the diatom assemblages, with diatom zones classified with the same height range. Diatom zone A, with predominant polyhalobous and planktic taxa, and significant mesohalobous taxa indicates a strong marine affinity. The zone is correlated to tidal levels about MLWS to MSL, where the frequency of daily tidal inundation ranges from 90-49%. In diatom zone B, the predominating mesohalobous assemblage characterises the brackish conditions. Also, abundant tychoplanktic and epipelic assemblages with reduced polyhalobous and planktic taxa are indicated. The zone is correlated with the tidal frame from about MSL to mid-point of MHWS to EHW, inundated daily from 40-4%. Diatom zone C depicts a narrow zone correlated with about ½- to ¾- (MHWS to EHW) tidal levels, daily inundation <1%. The zone shows an increase in the aerophilous assemblage, corresponding to the less frequent inundation of the site.

Pollen zone B correlates with diatom zone D, both showing a predominantly freshwater assemblage. The coastal freshwater swamp pollen prevails in the zone (to 85%), while the mangrove, back mangrove and the inlands inclusive assemblages are low. The halobian diatoms in the zone are almost completely comprised of the freshwater oligohalobous indifferent taxa. In the life form group, the epipelic taxa prevail while aerophilous taxa show a peak. The microfossil zone occurs around the EHW tidal level, tide influence being only felt during the 'extreme' high.

Pollen zone D, equivalent to diatom zone F, reflects an environment essentially free from a saline influence but showing a strong terrestrial input. The inlands inclusive pollen assemblages are abundant with low coastal freshwater swamp, back mangrove and the mangrove taxa. The salt-intolerant freshwater diatom assemblage, the halophobous group, occurs only in this zone and in abundance. Other assemblages that abound include the epiphytes, epipelic and the freshwater oligohalobous indifferent. The sampled environment, near coast and supratidal about 1.75 m above the EHW tidal level, is not very useful for the precise determination of the indicative meaning, but it contributes to the better understanding of the associated microfossil assemblages and characteristics.

Table 7.2. Summary of altitude, vegetation, frequency of tidal inundation, pollen and diatom characteristics from the Kuantan contemporary sites.

Sample no.	Altitude (m)	Vegetation	Frequency (%) daily inundation	Pollen characteristic	Diatom characteristic
KUPS15	3.756	Coastal *Pandanus* swamp	supratidal	Inlands inclusive assemblages well represented. Mangrove, back mangrove and coastal freshwater swamp are present. Fern and fungal spores increase. Pollen zone D. Supratidal.	Abundant *Eunotia tenella, Frustulia rhomboids, Pinnularia subcapitata*. Abundant halophobous, olig. indiff., epiphytes and epipelic assemblages. Zone F. Supratidal.
KUPS14	3.740	Coastal *Pandanus* swamp	supratidal		
KUPS13	3.566	Coastal *Pandanus* swamp	supratidal		
	1.816	EHW		Predominant Cyperaceae. Coastal freshwater swamp taxa prevail (65-85%). Others low. Pollen zone B. Correlates to around EHW tidal level.	Abundant *Navicula avonensis, Nitzschia pusilla, Nitzschia parvula* and *Pinnularia obscura*. Predominant olig. indiff., epipelic. Peak aerophilous. Zone D. Correlates to about EHW tidal level.
KUS16	1.799	*A. aureum* vegetation	No record		
KUS17	1.777	*A. aureum* vegetation	No record		
	1.571	¾ of MHWS to EHW	<0.3	*Rhizophora* spp. predominates. Mangrove is dominant (39-67%). Coastal freshwater swamp assemblage well represented (6-32%). Low back mangrove (<13%). Persistent inland taxa (13-39%). Pollen zone A. Correlates to reference water level from about MLWS to ¾(MHWS to EHW) tidal level.	Increase aerophilous taxa. Significant poly-, meso-halobous, planktic and epipelic. Zone C. Correlates to about ½- to ¾- (MHWS to EHW) tides.
KUS18	1.465	*A. aureum* vegetation	0.3-0.7		
KUS15	1.334	Mangrove tidal swamp	~1		
	1.326	mid of MHWS to EHW	~1		
KUS19	1.100	*Nypa* swamp	4-5		Abundant *Amphora coffeaeformis* and *Achnanthes delicatula*. Predominant mesohalobous. Abundant tychoplanktic, epipelic. Significant olig. halophile and episammic. Reduced polyhalobous and planktic assemblages. Diatom zone B. Correlates to about MSL to mid of MHWS to EHW tidal level.
KUS20	1.098	*Nypa* swamp	4-5		
KUS13	0.999	Mangrove tidal swamp	6-7		
KUS11	0.862	Mangrove tidal swamp	9-10		
	0.836	MHWS	10-11		
KUS9	0.723	Mangrove tidal swamp	13-14		
KUS21	0.709	*Nypa* swamp	14-16		
KUS7	0.505	Mangrove tidal swamp	21-23		
	0.426	MHWN	24-25		
KUS5	0.147	Start of mangrove aerial roots	38-40		
	0	MSL	49-51		High *Thalassionema nitzschioides, Coscinodiscus blandus* and *Cyclotella striata*. Predominant polyhalobous and planktics. Significant mesohalobous. Diatom zone A. Correlates about MLWS to MSL.
KUS3	-0.263	Unvegetated tidal estuary slope	67-69		
	-0.434	MLWN	75-77		
KUS1	-0.620	Unvegetated tidal estuary slope	84-86		
	-0.764	MLWS	88-90		

7.2.3 Comparison of Kelang and Kuantan data

The microfossil association in Kelang and Kuantan shows marked contrasts at differing reference water levels. In Kelang the pollen and diatom assemblages recorded significant change around the mid-point of MHWN to MHWS tides where a brackish environment replaces the basically marine conditions. For Kuantan, the significant pollen and diatom changes are recorded around the EHW, indicating the shift from marine influence to a prevailing freshwater condition.

The contrasting change in microfossil assemblages at different water levels expressed in Kelang and Kuantan contemporary sites are probably related to the geomorphological setting of the sites and the less complete Kelang data compared to Kuantan. The sampling sites in Kelang are from the mangrove vegetated open coast, which is subjected to tidal and wave action, whereas the *Nypa* vegetation is slightly affected by the tides only (Figs. 5.6, 5.8 & 5.9). The prominent change in pollen data indicated from the mid-point of MHWN to MHWS is mainly due to the pollen contributed from the *Nypa* vegetation (KES20, KES19, KES21). The contrast displayed in the Kelang diatom data, which similarly starts from the mid-point of MHWN to MHWS shown by samples from the mangrove transect, indicate the switch to brackish conditions around this altitude. In the Kuantan data, the significant increase of similar diatom assemblages is also recorded around the mid-point of MHWN to MHWS.

All the contemporary sampling sites in Kuantan are in sheltered environments away from the open sea (Figs. 5.14 & 5.15). The mangrove transect is at the bank of Kuantan estuary where tides rather than waves are prevalent. The *Nypa* swamp site shows an open connection with the estuary where tide movement is easy flowing compared to the *Nypa* vegetation at Kelang. The prominent microfossil shift in Kuantan contemporary data is around EHW. But diatom data do record changes below this level, as indicated by the diatom zones A, B and C. Also, as noted above, the significant increase of mesohalobous and episammic assemblages, but less distinct compared to Kelang, is observed from around the mid-point of MHWN to MHWS. The obvious microfossil change around the EHW is evidently tide related pointing to a clear boundary between fresh- and brackish- water. In the Kelang data the outcome around the EHW is not known since the sampling does not reach that altitude. Nevertheless, from about MHWS level, pollen data in Kelang does reveal changes implying increasing terrestrial influence as discerned by the pollen zone D.

7.3 Indicative meaning of the sea level indicator

The indicative meaning of the sea level indicator is its altitudinal relationship to the contemporaneous reference tide level (Plassche, 1986a; Shennan, 1982a, 1986b). Microfossil analyses of the regressive contacts of the fossil sediments reveal biostratigraphic changes indicating shifts from marine influence to brackish and fresh water conditions. The interval where biostratigraphic change occurs, determines the indicative range of the sample. The indicative range can be reduced by dating the level at which the microfossil and stratigraphic evidence reveal a change in the sedimentary environment. From that horizon, the sea level indicator samples were subsequently dated.

7.3.1 AMS radiocarbon dating results

A total of seven sea level indicator samples from three transects, two from Meru, four from Mardi, and one from Penur (north), were AMS ^{14}C dated. Preliminary palynological analysis, prior to selection of the samples for dating indicate vertical changes in the pollen assemblages from marine to brackish and freshwater sequences. The change approximately coincides with the position of the regressive contact of the lithostratigraphic layers, the base of the upper peat with the lower clayey/silty marine sediment. Generally at each regressive contact, reduction of the mangrove assemblage is indicated, back mangrove and/or coastal freshwater swamp increase, while the composition and diversity of other floral communities also start to rise. Samples for dating were thus taken from the base of the peat overlying the clastic layer, except for KUC15 where the sample was from about the top of the peaty clay underlying the peat.

Table 7.3 shows the AMS ^{14}C dating results of the seven sea level indicators. Both conventional and calibrated (Stuiver et al., 2000) dates are presented. The latter are the age ranges, which contain 95.4% (2σ) of the area under the probability distribution curve (Pilcher, 1991).

7.3.2 Indicative meaning interpretation

The indicative meaning of the fossil sea level indicator is determined by comparing its microfossil assemblages to the contemporary results. The indicative range and meaning of the dated samples are then interpreted. The interpretation of the indicative range, in cases, is fairly subjective. This is especially so when the fossil and contemporary biozones do not show good correlation. The indicative range in this case is approximately estimated from the closest analogue in the fossil sequence. Difficulty in estimating the indicative meaning could arise when there is a significant difference in microfossil composition and representation between the fossil and contemporary assemblages and by the incomplete contemporary picture for the whole tidal sequence in the contemporary dataset. The latter is due to the large vertical sampling interval or an incomplete sampling done.

Table 7.3. AMS ^{14}C dating results.

Site & Core no.	NERC Lab. Code	Depth (cm)	Altitude to MSL (m)	Geographical co-ordinates		Material	Conventional ^{14}C age (B.P.$\pm 1\sigma$)	Calibrated age ranges (Calendar year BP)
				N	E			
Meru, KEC2	AA37792	70-71	4.193-4.203	3°09'	101°27'30"	In situ woody peat overlying marine clastics	4045±49	4647-4413
Meru, KEC1	AA37793	109-110	4.304-4.314	3°09'14"	101°27'48"	In situ woody peat overlying marine clastics	4073±86	4831-4404
Mardi, KEC9	AA37794	190-191	4.936-4.946	2°59'08"	101°29'42"	In situ woody peat overlying marine clastics	5331±46	6202-5989
Mardi, KEC8	AA37795	174.5-176	4.675-4.69	2°59'08"	101°29'48"	In situ woody peat overlying marine clastics	5270±47	6120-5927
Mardi, KEC7	AA37796	70-71	4.787-4.797	2°59'14"	101°29'59"	In situ woody peat overlying marine clastics	5349±65	6213-5989
Mardi, KEC13	AA37797	95-96	4.738-4.748	2°59'19"	101°30'33"	In situ woody peat overlying marine clastics	5556±47	6411-6280
Penor (north), KUC15	AA37798	46-48	3.034-3.054	3°43'22"	103°16'27"	Peaty clay	3967±43	4527-4344

Pollen and diatom assemblages determine the indicative meaning of the dated samples KEC2 and KEC1. For other dated samples, KEC9, KEC8, KEC7 KEC13 and KUC15, the indicative meanings are determined only from their pollen assemblages, since diatoms are rare or absent.

7.3.2.1 Indicative meaning of sea level index 1

The pollen assemblage of the dated horizon (the sea level indicator) of core KEC2 shows decreasing mangrove, increase back mangrove and high fern spores (pollen zone 2; Fig. 6.8). This is approximately correlated to the base of the Kelang contemporary pollen zone C (Figs. 6.1 & 7.1). In the diatom diagrams (Figs. 6.16 & 6.17), the dated level (fossil diatom zone 2) indicates reduced polyhalobous with increasing mesohalobous and abundant planktic assemblages, is approximately correlated to the Kelang contemporary diatom zone B (Figs. 6.4, 6.5 & 7.1). From pollen and diatom information, the indicative meaning of KEC2 is estimated at approximately slightly above the mid-point of MHWN to MHWS, which also suggest the point of initiation when peat starts to accumulate. Both the pollen and diatom assemblages in KEC2 indicate marine influence is present above the regressive contact.

As an example, the above interpretation is referred to Fig.7.1 and the SLI1 quantified. Diatom zone B is estimated to range from 1.00 to 1.35 m altitude MSL. The base of pollen zone C is estimated to range from 1.35 to approximately 1.60 m MSL. Thus the indicative range (IR) is interpreted to range from 1.0 to 1.60 m MSL. The IM of the dated horizon of core KEC2 equals 1.3±0.3 m MSL. Table 7.4 lists the interpreted indicative meaning and range of the sea level indicators, or the sea level index (SLI) points.

Table 7.4. Indicative meaning (IM) estimated from the dated sea level indicator in Kelang and Kuantan.

Core no.	Altitude (m) of sea level indicator (Dated level)	SLI interpretation	Relation of fossil sea level indicator to contemporary reference water level	
			Indicative range (m)	Indicative meaning (m)
KEC2	4.193-4.203	IM 1	1.0-1.60	1.30±0.3
KEC1	4.304-4.324	IM 2	1.40-1.80	1.60±0.2
KEC9	4.936-4.946	IM 3	1.40-1.60	1.50±0.1
KEC8	4.675-4.69	IM 4	1.40-1.80	1.60±0.2
KEC7	4.787-4.797	IM 5	1.40-2.0 (~Pollen Zone C)	1.70±0.3
KEC13	4.738-4.748	IM 6	1.20-1.60	1.40±0.2
KUC15	3.034-3.054	IM 7	1.70-1.90 (Pollen Zone B)	1.80±0.1

7.3.2.2 Indicative meaning of SLI 2

The dated sample of KEC1, represented by pollen zone 2 (Fig. 6.9), indicates a zone of significant biostratigraphic change from marine to brackish, shown by a drastic decrease of mangrove, predominating back mangrove and is below the increase of coastal freshwater swamp assemblages. The indicative range of the dated sample is estimated to approximately correlate with the lower half of the Kelang contemporary pollen zone C. Fossil diatom analysis however could not precisely define the horizon of the dated sample due to the absence of, or very rare, diatoms (Figs. 6.18 & 6.19). However, assemblages below the dated level suggest that the indicative meaning lies approximately in the reduced plankton and increase epipelic zone, implying diminishing marine effect with more exposed sediment surface, or in diatom zone C (Fig. 7.1). The indicative meaning of KEC1 is estimated at just above the mid-point of MHWN to MHWS.

7.3.2.3 Indicative meaning of SLI 3

The indicative meaning of the dated sample in KEC9 (Fig. 6.10), classified within pollen zone 1b, is estimated at around the mid-point of MHWN to MHWS. Pollen zone 1b shows decreasing mangrove and just below the rise in coastal freshwater assemblages. It is correlated to about the base of the contemporary pollen zone C (Fig. 7.1).

7.3.2.4 Indicative meaning of SLI 4

The dated KEC8 sample lies within pollen zone 2 that records decreasing mangrove, increase back mangrove and below the coastal freshwater swamp (Fig. 6.11). The zone is correlated to about the lower half of the contemporary pollen zone C (Fig. 7.1). The indicative meaning of the dated sample is estimated slightly above the mid-point of MHWN to MHWS.

7.3.2.5 Indicative meaning of SLI 5

In KEC7 the dated sample lies at the boundary of pollen zones 1 and 2 (Fig. 6.12). The mangrove is at a point of declining while the coastal freshwater swamp and the inland assemblages are about to increase. The back mangrove had just passed its peak. The dated zone is correlated to approximately contemporary pollen zone C (Fig. 7.1). The indicative meaning thus lies about ¾ of MHWN to MHWS

7.3.2.6 Indicative meaning of SLI 6

The dated sample of KEC13 lies in the lower part of pollen zone 2 (Fig. 6.13). It is at the level where *Rhizophora* spp. is reduced and also, well below the zone of increasing back mangrove assemblage. The peak in *Pandanus* spp. is probably due to local over representation. The dated sample is approximately correlated to the lower part of pollen zone C or quite likely the upper zone B (Figs. 7.1 & 7.2). The indicative meaning is estimated at about the mid-point of MHWN to MHWS or slightly lower.

7.3.2.7 Indicative meaning of SLI 7

The dated sample from KUC15 (the only sea level indicator from the east coast study site) is represented by pollen zone 3 (Fig. 6.14) and correlated with the Kuantan contemporary pollen zone B (Figs. 6.2, 7.3, 7.4). Within the zone, both fossil and contemporary pollen show characteristic abundance and domination of the coastal freshwater swamp assemblage while mangrove is very much reduced. The dated sample also lies below the significant rise in the inland inclusive assemblages. The indicative meaning of the of KUC15 corresponds to about the EHW tidal level (Fig. 7.3).

CHAPTER 8

HOLOCENE RELATIVE SEA LEVEL CHANGES

8.1 Introduction

This chapter presents the interpretation of the sea level index points identified in this study. Comparison with methods previously employed in determining the sea level index points in the area and neighbouring localities are discussed. Comparisons of the sea level results with existing geophysical model predictions for the region are also made.

8.2 The age-altitude model

Seven sea level index points are available from this study, six from Kelang in the west coast and one from Kuantan in the east. Each index point is characterised by a geographical location, an altitude, age, indicative meaning and a tendency. The index points all show negative tendencies of sea level movement, indicated from the lithology and the microfossil results. The regressive overlaps shown by the peat overlying marine sediments, and the results of pollen and limited diatom analyses point to a removal of marine conditions from the sites. Table 8.1 lists the essential sea level index attributes. An example of the index point calculation is given in Chapter 7 (specifically 7.3.2.1).

Table 8.1. Sea level index points from Kelang and Kuantan

Core no.	AMS ^{14}C age BP (1σ)	Calibrated age ranges Cal. years BP (2σ)	Altitude (m) of sea level indicator (Dated level) [X]	Indicative meaning (m) [Y]	Relative paleo sea level (m) [(mid X)-Y]	Sea level tendency
KEC2	4045±49	4647-4413	4.193 to 4.203	1.30±0.3	2.898±0.3	-ve
KEC1	4073±86	4831-4404	4.304 to 4.314	1.60±0.2	2.709±0.2	-ve
KEC9	5331±46	6202-5989	4.936 to 4.946	1.50±0.1	3.441±0.1	-ve
KEC8	5270±47	6120-5927	4.675 to 4.69	1.60±0.2	3.08±0.2	-ve
KEC7	5349±65	6213-5989	4.787 to 4.797	1.70±0.3	3.092±0.3	-ve
KEC13	5556±47	6411-6280	4.738 to 4.748	1.40±0.2	3.343±0.2	-ve
KUC15	3967±43	4527-4344	3.034 to 3.054	1.80±0.1	1.244±0.1	-ve

The sea level index points are plotted on a time-altitude graph (Fig. 8.1). In this study only errors arising from the estimation of the indicative meaning and the calibrated ages are considered. In the former the error is estimated by comparing the altitude of the fossil with that of the contemporaneous assemblages while the latter is the variation of the calibrated age range from its mid point value. Errors that may arise from the measurement of altitude of stratigraphic boundaries (Shennan, 1982a, 1986b), due to coring and levelling are quite difficult to the estimate and are assumed to be negligible. Nevertheless throughout the whole process of data procurement, care and adherence to standards have always been strictly followed, so as to reduce and minimise any source of error that may arise. This analysis assumes that the paleotides are similar and had behaved in a constant manner to the present day. No data on numerical modelling of paleotidal ranges exist from the area investigated.

8.2.1 Kelang sea level analysis

The Kelang sea level plot (Fig.8.1) shows clustering of index points from the two areas of study, Meru and Mardi. They both show high sea level, higher than present MSL, at around the mid Holocene. In Mardi the values are approximately 3.1-3.4 m in altitude dated around 5.3-5.6 ka BP (5.9-6.4 ka cal. BP), while in Meru about 2.7-2.9 m at 4.0-4.1 ka BP (4.4-4.8 ka cal. BP). The index points of the former are higher and older than the latter.

The clustering of the index points at Mardi and Meru could imply that there is a discontinuous sea level progression between about 5.3-5.6 to 4.0-4.1 ka BP (5.9-6.4 and 4.4-4.8 ka cal. BP). This would mean a fluctuating sea level between the two periods. Fig. 8.2 depicts the hypothesised sea level trend (marked in red). For a fluctuating sea level, both negative and positive tendencies of sea level movement should normally be recorded (Shennan, 1987). This would only happen when the lithostratigraphy records intercalated marine and freshwater deposits. As far as the Kelang stratigrapy is concerned, there is not much variation of its lithology laterally, the coastal peat is generally observed overlying the marine sediments. Intercalated mid-Holocene peat layers have not been recorded in Kelang or from other parts of the peninsular west coasts (Figs. 5.10 & 5.11; Bosch, 1988). However, interlayered peat deposits of late Holocene/early Pleistocene and older are known from the Strait of Malacca and the South China Sea (Biswas, 1973; Geyh et al., 1979; Kamaludin et

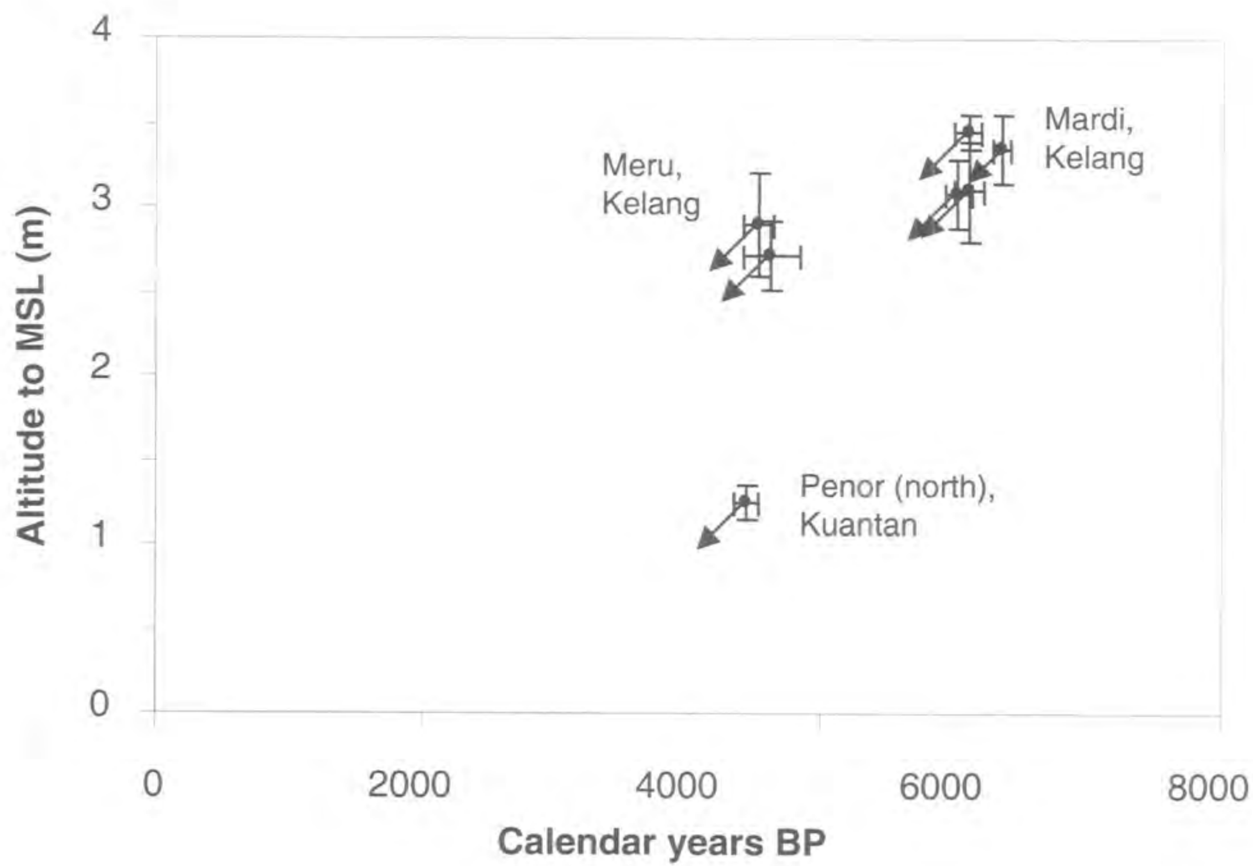


Fig. 8.1 Plot of sea level index points.

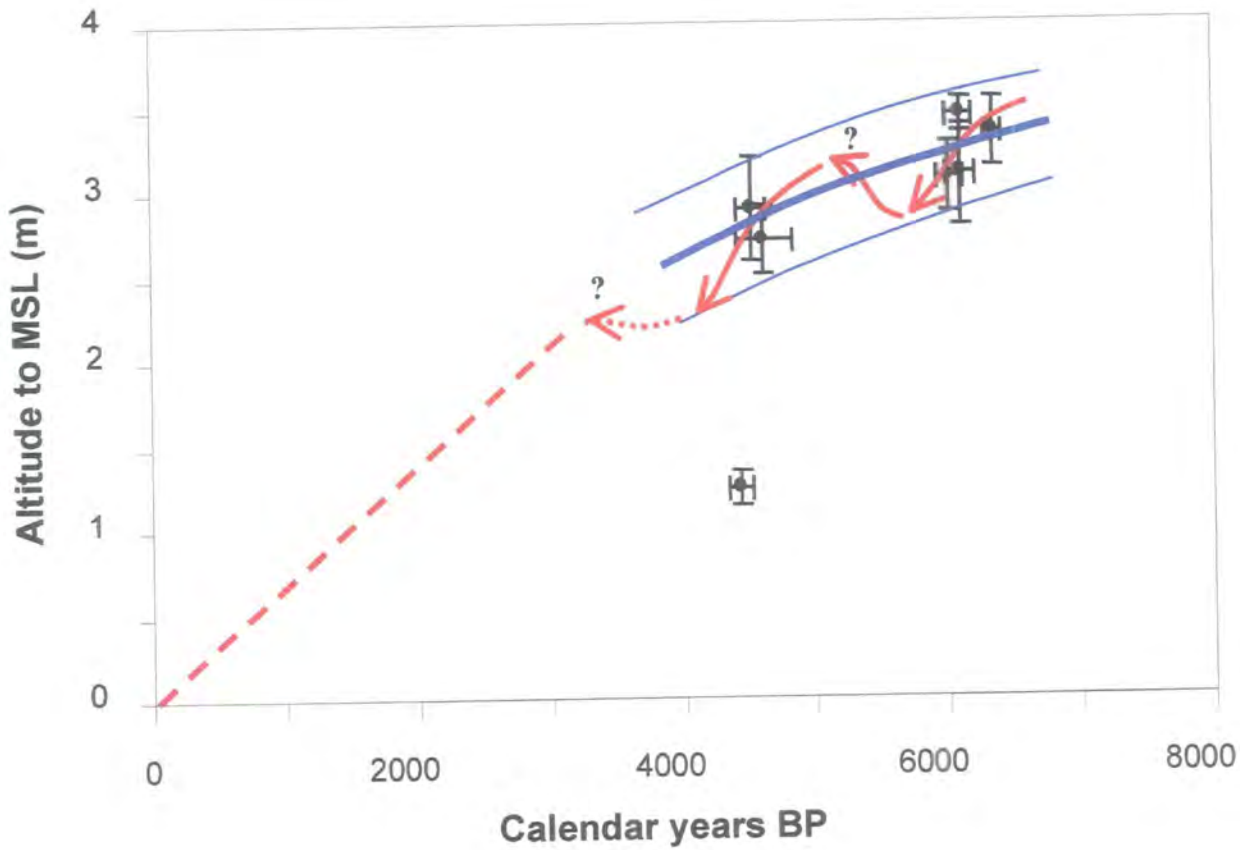


Fig. 8.2 Hypothesised fluctuating sea level lowering at Kelang.

al., 1993). The gap in index points in Mardi and Meru, and also the large break of data from 4.0-4.1 ka BP to the present, could probably be bridged by the collection of more sea level data from both the localities, the latter presumably from the base of peat layers closer to the present coast and at lower elevations.

The presumed sea level trend in Kelang is as shown in Fig. 8.2, marked by the thick blue line. The bordering faint blue lines refer to the sea level band indicating the estimated maximum and minimum values.

8.2.2 Kuantan sea level analysis

There is only one sea level index point from Kuantan area, from the Penor (north) site. As in Kelang, the Penor (north) index point also shows high sea level, higher than present MSL, near the mid Holocene. The index point has a value of about 1.2 m altitude dated approx. 4.0 ka BP (4.3-4.5 ka cal. BP).

The Penor (south) transect, however, yields no index points. The ground at Penor (south) is comparatively higher compared to Penor (north). The more elevated ground level means that marine influence does not reach the site. Even though the stratigraphy shows an interesting sequence of peat and clastic sediments, microfossil results indicate that the deposits had accumulated in a freshwater environment (Fig. 6.15). The lowest altitude of the peat/clastic contact in the Penor (south) transect is measured at approx. 3.90 m (about 178 cm depth in KUC12), while the elevation of the sea level indicator from the Penor (north) site indicates the marine/freshwater boundary is at around the 3.0 m level.

As noted earlier on, the Kuantan investigation is only an experimental test of the sea level research methodology for the east coast. The study has nevertheless proved successful even though only one index point was identified. The stratigraphy from the Penor (north) transect suggests that other index points could similarly be expected to be within the level of the dated KUC15 horizon.

8.2.3 Kelang and Kuantan sea level analysis

The sea level index points in the Kelang and Kuantan sites show that around the mid-Holocene both the disparate locations exhibit higher sea levels than the present. The Kuantan index point (KUC15) is of similar age to that from Kelang

(KEC1 & KEC2), but a difference of about 1.4-1.6 m is noted between these index points(Table 8.1).

Since there is only one sea level index point from Kuantan, the significance and interpretation of the relative sea level difference between the area and Kelang, must be made with caution. On the one hand the relative difference could imply differential crustal movement between the west and east coasts of the peninsula, which could probably be resulted from isostatic, eustatic and tectonic effects. These may reflect the combined effects of hydroisostasy, geoidal- and/or tectono- eustasy. But on the contrary, the relative sea level difference of 1.5 m may simply reflect the age/altitude variability inherent in the sea level index points from this region. The latter is noted from the much study area of the east coast of England (Shennan et al., 2000b). For example, in the Northumberland, Humber Estuary, Tees Estuary, North Norfolk and Fenland, and especially the latter, the sea level index plots show a vertical scatter of approximately 3-5 m between *c*. 6000-3000 calibrated years BP. This is certainly two to three times the value indicated between Kelang and Kuantan. Whether the reason for the relative sea level difference in Kelang and Kuantan is related to differential crustal movement or as yet undefined uncertainties in the age/altitude validity of the index points, it is clear that more sea level index points are required from Kuantan to ascertain the finding. Since it is still preliminary to ascribe differential crustal movement as the probable reason for the relative sea level difference, much prudence is exercised when discussing the issue.

8.3 Synopsis of Holocene sea level changes in Southeast Asia

Before engaging in an in-depth discussion on the relative sea level changes of the study area, a general synopsis of the region's Holocene sea level records would be beneficial. The following summary briefly describes the southeast Asia sea level studies (apart from Malaysia, which has been discussed in Chapter 2), from south India in the west, to Sri Lanka, Bangladesh, Thailand, Singapore, Indonesia, Hong Kong, and south China in the east.

In south India, Banerjee (2000) indicated about 3 m higher than present level around the mid-Holocene. Biological sea level indicators, including hermatypic coral colonies, molluscs and shells, were ^{14}C dated at about 6.5 ka and 4.8-4.1 ka BP. Similarly, in the south coasts of Sri Lanka, Katupotha and Fujiwara (1988) showed of at least one metre higher than present MSL from coral and shell samples, which were ^{14}C dated at 6.1-5.1 ka and 3.2-2.3 ka BP.

In Bangladesh, Islam and Tooley (1999) reconstructed the Holocene sea level history using litho-, bio- and chronostratigraphic techniques. Throughout the Holocene, a general sea level rise to the present is depicted with no higher than present sea level observed.

Sinsakul et al. (1985) and Sinsakul (1992) compiled the Holocene sea level records from Thailand and presented them in the conventional age/altitude plots. The ^{14}C dated sea level data were from peat, shells and wood. A widely scattered data distribution (above and below the x-axis) ranging from about –8 m to +5 m altitude MSL and dates from about 8.6 ka to 1.2 ka BP are respectively represented. Describing the trend of sea level progression would indeed be quite a task from this plot. Nevertheless, geomorphological data indicative of high sea levels around the mid-Holocene is considerable. The earliest higher than present sea level of about 3.8 m was recorded around 6.5 ka BP.

Hesp et al. (1998) proposed a first tentative Holocene sea level curve for Singapore. They ^{14}C dated peat, oyster, corals, shells and wood, and suggested that around the mid-Holocene the sea level was about 3 m higher than present MSL.

Hantoro (1997) outlines the Holocene sea level curve for western and central Indonesia (covering the islands of Java, Bali, Sumbawa, Lampung, Alor, Timor, Rote, Sabu and Sumba). The sea level data points all show higher than present level, reaching up to about 3.1 m and spanning dates between about 7.2 ka to 0.8 ka BP.

In Hong Kong, Davis et al. (2000) noted higher than present sea level for the mid-Holocene. The ^{14}C dated oyster horizon indicates that at about 5.1 ka BP the south China area was 4-5 m higher with respect to the Principal Datum (2.7 m below high tide mark) than at present. Further north, in the Han River Delta, south China, Zong (1992) studied the postglacial sea level changes using historical records, litho- and chronostratigrapic techniques. Three periods of marine transgression followed by regression were identified. The history of sea level changes during the Holocene is documented as rapid risings before about 4.3 ka BP, while thereafter as slight fluctuations. In contrast to that reported from Hong Kong, there is however no evidence to suggest a higher than present sea level around the mid-Holocene from the Han River Delta.

It is obvious that mid Holocene higher than present sea level is widespread in the region. These dates mainly span from about 6.5 ka, except for Indonesia from about 7.2 ka, to approximately 1 ka BP with sea levels varying from 1 to 5 m above the present. Such a widespread highstand suggests local tectonic as unlikely to explain the patterns observed. However, in the studies, except Zong (1992), none of the sea level indicators were corrected their indicative meaning. These low-resolution post glacial sea level data is peculiar for the region.

8.4 Discussion

With reference to the present finding, comparison is made with other related sea level investigations and geophysical modelling of Holocene sea level changes in the region. The significance of this study and its results to previous sea level methodologies are explored.

8.4.1 Comparison between this study with previous records

The Holocene sea level changes depicted by Geyh et al. (1979) from the Strait of Malacca study is (Fig. 2.3), however, deficient from the bio- and litho-stratigraphic points of view. Even though Streif (1979), discussed briefly the indicative meaning of the dated material, the indicative range of the sample, uncertainties of height determination and the sigma interval of the ^{14}C dates, the fact that the stratigraphy and most importantly biostratigraphic analysis were not dealt with, reduces the significance of the interpretation. Figure 8.3 shows plots of the sea level index points of the present study (blue circle), as compared to if they were similarly interpreted using the Geyh et al. (1979) and Streif (1979) methodology (red triangle). It is noted that the index points from present study are altitudinally lower by the value of their indicative meaning, than if they were plotted in the latter. The importance of indicative meaning is further illustrated in the sea level plot of Geyh et al. (1979), as shown in Fig. 2.3, where the sea level indicators 7583 and 7586 show approximately 3 m height difference even though the dates of both samples were quite close. The sample 7583 was described as 'mangrove and peat above terrestrial deposits' while the sample 7586 as 'peat to fresh water deposit on top of brackish sediments'. Since no microfossil and stratigraphic analyses were conducted to

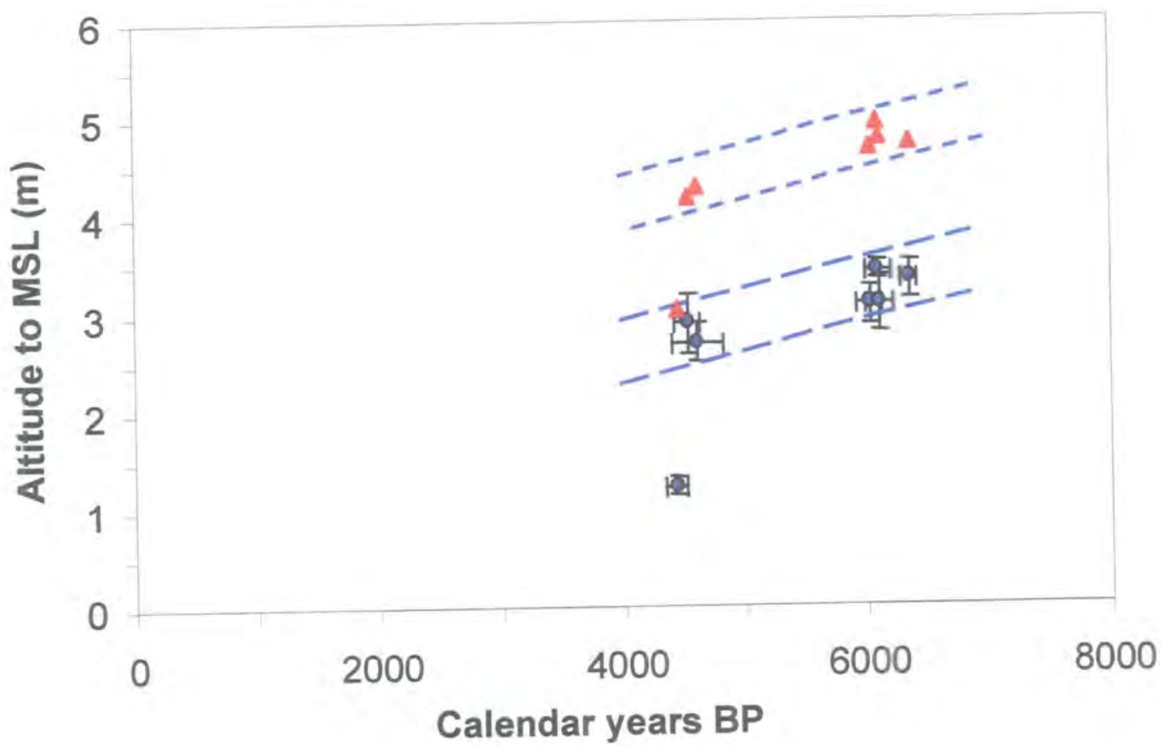


Fig. 8.3 Plot of sea level index points, with and without the indicative meaning values.

ascertain the indicative meaning of the indicators, they could presumably represent any point in the tidal frame between MSL to the EHW, thus the large height difference. The sea level interpretation of Geyh et al. (1979) and Streif (1979) are, in addition, quite misleading since all the indicators were plotted in a single sea level curve. The data points from the Strait of Malacca survey cover a long stretch of about 300 km of the peninsula southwest coast. Shennan (1987), Pirazzoli (1996) and Shennan et al. (2000a) point out that sea level changes vary between places, regionally as well as locally.

In the study by Tjia (1970, 1980, 1992, 1996) and Tjia et al. (1977), the mid Holocene to present sea level of peninsular Malaysia is investigated from the morphological feature and shoreline biological indicator, the former includes the coasts and sea floors while the latter such as oysters, barnacles, molluscs and shells. For the sea level methodology to be useful, any index point determined needs to satisfy the criteria of age, altitude, geographical location, tendency and indicative meaning (Plaasche, 1986b; Shennan, 1986b). However Tjia's technique lacks the latter two, particularly the indicative meaning of the sea level indicator. The altitude of the indicators was also mostly based on estimated values like above or below high tides, except only 15, where shoreline indicators were levelled (in Yoshikawa, 1987). In addition, more than 130 index points (Tjia designates as shoreline indicators) collected from all parts of peninsular Malaysia were interpreted in a single sea level graph to represent the peninsula Holocene sea level diagram, thus the dispersed data points (Fig. 2.5). No specific indicative trend could obviously be deciphered from the very wide spread index points, even though the west and east coast data were differently labelled. A high mid Holocene sea level, up to about 5 m above MSL is indicated. The three suggested routes of sea level falls (Tjia, 1992 and 1996), depicted as fluctuating, progressive but gradual lowering, and stepwise recession are but merely loose postulation.

The respective sea level plots from the north and south of peninsular Malaysia, in Thailand by Sinsakul et al. (1985) and Sinsakul (1992), and from Singapore by Hesp et al. (1998), similarly, fails the definition of sea level index points. The majority of the plots in Thailand for instance, are just points which record the altitude of the presumed sea level indicator, which in cases does not even qualify to be a sea level index point. Examples include shells and wood in marine sediments, which could be transported and also difficult or rather impossible to determine their indicative meaning, but have been used as the sea level indicator. In many others, the elevation was estimated using topographic maps. Even though Sinsakul et al. (1985) discusses the sea level fundamentals and its error sources, no mention of the sample indicative meaning and tendency is given. Meanwhile, among the Singapore sea level indicators, the ^{14}C dated peat samples were not biostratigraphically examined. In one supposedly sea level indicator sample, the peat was dated 45 cm above from its regressive basal contact. Thus proper re-evaluation of the sea level data from Thailand (Sinsakul et al., 1985; Sinsakul, 1992) and Singapore (Hesp et al., 1998) are timely.

A reassessment of Geyh et al.'s and Tjia's data (compiled in Yoshikawa, 1987), two sea level plots representing the east and west coasts is attempted in Fig. 8.4. In each scatter plot is shown a line indicating estimates of the relative sea level fall from about 6000 BP. All the data points were assigned indicative meanings and error ranges. Table 8.2 lists the types of data available. Poor data points with an uncertain IM, like undifferentiated wood, peat and algae, were excluded. The IM and IR estimation are developed from concepts proposed by Shennan (1982a) and Zong (1992), and the results of present study. The oyster, molluscs in beach sand and beachrock are assumed 0 m IM because they could be present from the low to high tide range, while coral and molluscs in mud are estimated to occur within the low tidal zone. The mangrove wood, peat and wood on brackish deposits are presumed having similar IM (average) with the present study.

A total of 73 data points (including present study), 51 from the west coasts and 22 from the east were analysed. Both the plots show poor data resolution, since they represent wide area. The calculated linear rate of sea level fall for 0-6000 ^{14}C years BP in the east coasts is 0.3 mm/year and the west is 0.5 mm/year. Slight relative sea level difference between the east and west are probably cause by factors like hydrisostasy, sediment compaction, paleo-tidal changes, tectonic or also, the indicative meanings of different sea level index points (Shennan, 1989).

8.4.2 Geophysical modelling of postglacial sea level changes

The Holocene postglacial sea level rise modelled by Clark et al. (1978), classifies peninsular Malaysia within the 'zone IV-oceanic submergence' form of relative sea level curve. No emerged beaches but dominant submergence are

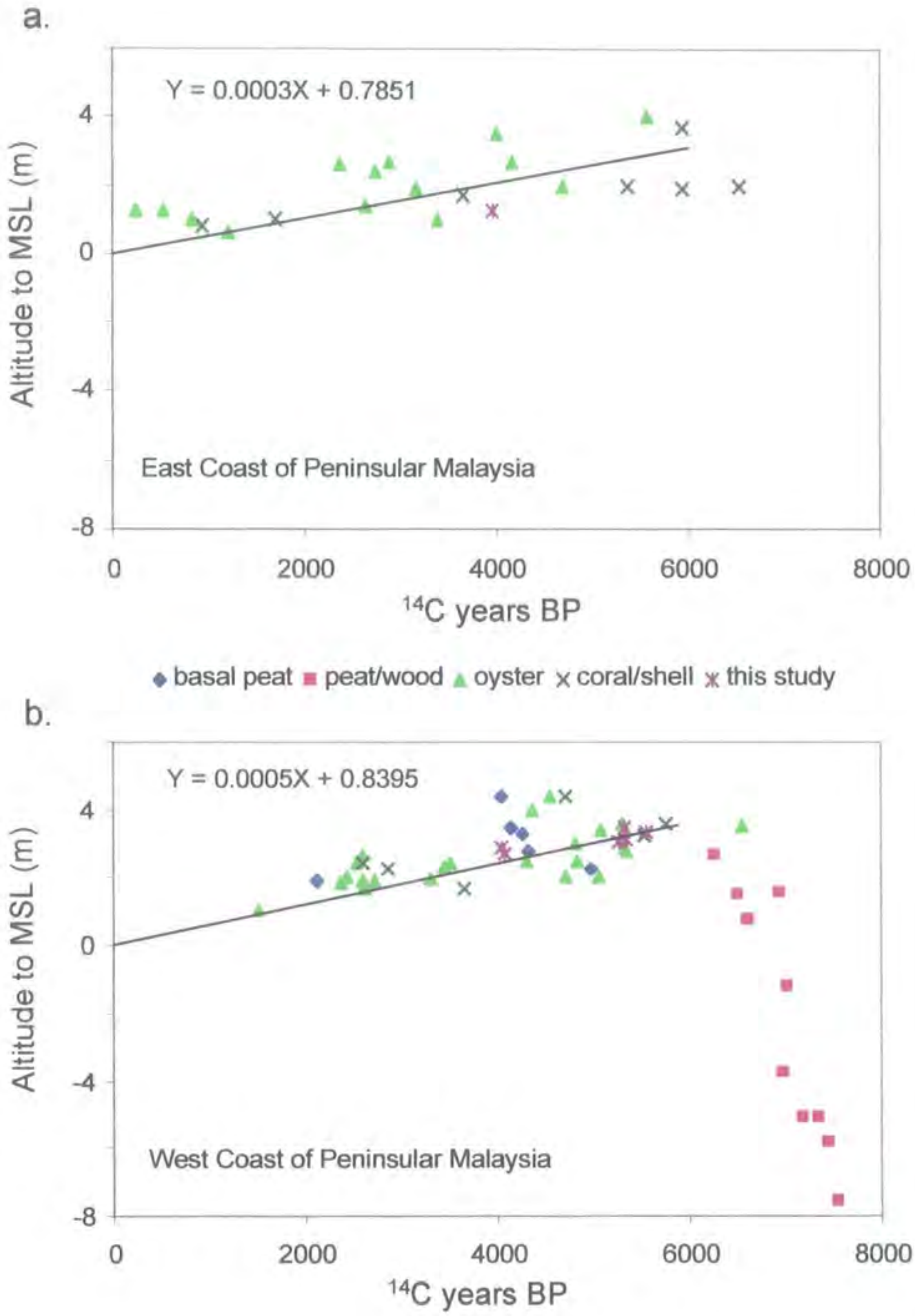


Fig. 8.4 Scatterplots of: a). east and b). west coasts index points (IM & IR corrected) and estimates of current rates of relative sea level fall.

predicted. Sea level is depicted at or near the present level at about 5,000-4,000 BP (Fig. 2.6). However, peninsular Malaysia has well developed Holocene coastal plains, higher than present sea level, straddling its west and east coasts. This alone contradicts the no emerged beaches view postulated by Clark et al. (1978). The fact that the results of this study indicate higher than present sea levels around the mid Holocene, 2.7-2.9 to 3.1-3.4 m in the west and about 1.2 m in east coasts, suggest that apart from hydroisostasy other factors may also have effect the Holocene postglacial relative sea level history of the peninsular Malaysia region.

Table 8.2. Estimated indicative meanings for Geyh et al.'s and Tjia's sea level data (shoreline data extracted from Yoshikawa, 1987).

Type of indicator	Indicative meaning (m)	Indicative range (m)
Oyster in growth position	0	±1.5
Coral in growth position	-1.5	±1.5
Molluscs in beach sand	0	±1.5
Molluscs in mud	-1.5	±1.5
Beachrock	0	±1.5
Mangrove wood on brackish deposits	1.5	±1.5
Peat on brackish deposits	1.5	±1.5
Wood on brackish deposits	1.5	±1.5

As summarised earlier, other high mid-Holocene records in the region: from south India, south Sri Lanka, Thailand, Singapore and Hong Kong, all within Clark et al.'s zone IV, may well point to the inaccuracy of the latter's model. In peninsular Malaysia, the plot of Fig. 8.5 (IM of all data points corrected and estimated) further illustrates that the relative sea level curve of the region disqualifies Clark et al.'s prediction but matches their zone V of oceanic emergence. The plotted error range is particularly notable for the Geyh et al.'s and Tjia's data but minimal for that from this study. What is evident from Fig. 8.5 is that postglacial eustatic rise in sea level starts to slow–down at about 7 ka BP. Subsequently, sea level was maximally about 4 m higher than present until about 4 ka BP, and thereafter with lower values. Also, the sea level graph indicates that both organic deposits and biological sea level

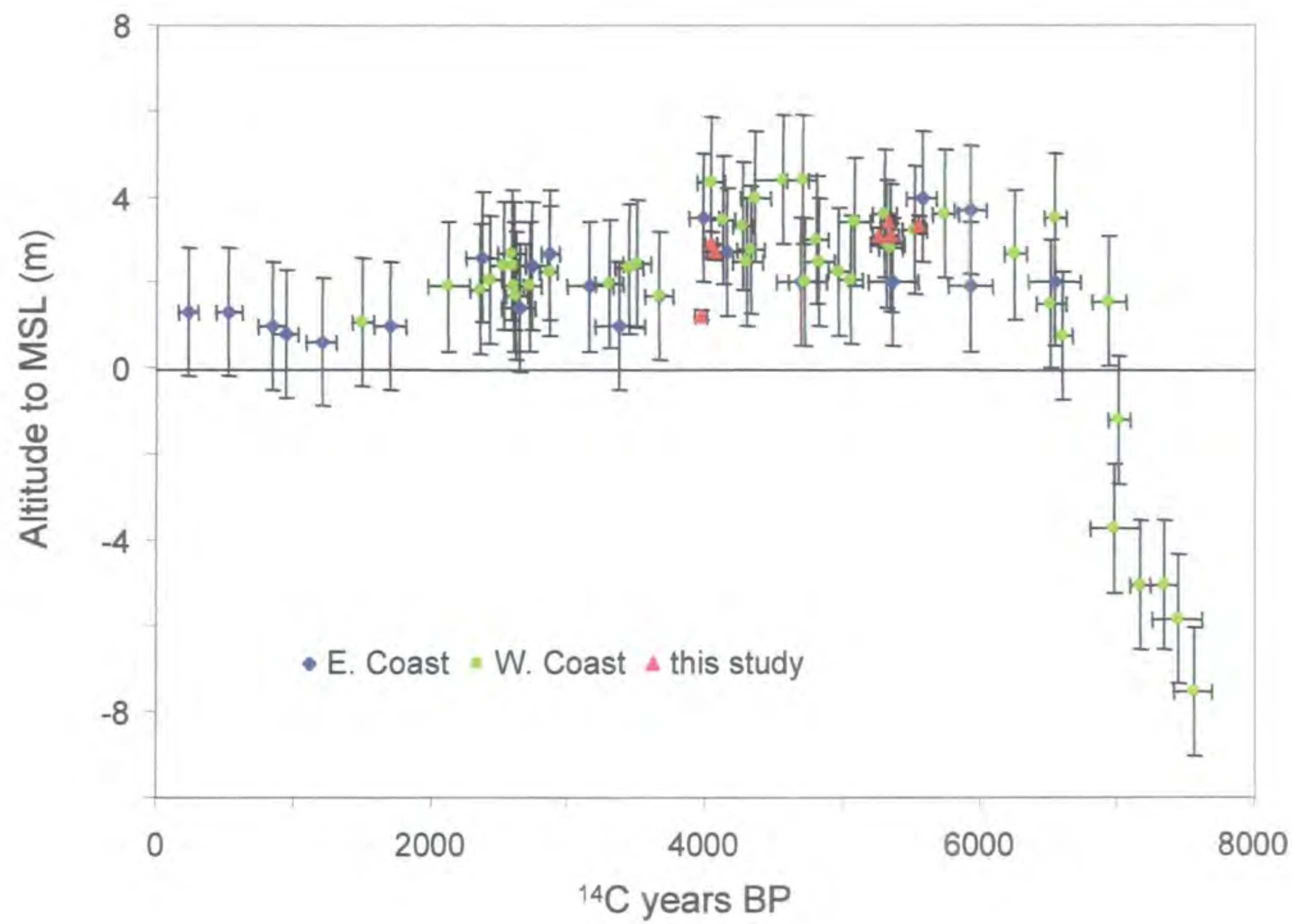


Fig. 8.5 Scatterplot of peninsular Malaysia sea level index points (IM & IR corrected), to about 7.5 ka BP. Note the large error range, especially altitudinally, compared to this study.

indicators are invaluable for better relative sea level reconstructions. The direct effect of the high mid Holocene sea level is manifested in peninsular Malaysia by the evolution of its coastal plains.

Peltier (1998) explained the postglacial sea level variations to the glacial isostatic adjustment (GIA), acknowledged the equatorial Pacific Ocean and its western margin (the 'far-field' region or part of zone IV of Clark et al. (1978)), achieving a highstand at 4-6 kyr ago. The predicted sea level history based upon the ICE-4G (VM2) model of the GIA process well predicts the amplitude and timing of the highstand in the region. The nearest site to peninsular Malaysia modelled by Peltier (1998) is the Sumba island of Indonesia, which is about 2,000 km southeast. The sea level model based on ICE-4G (VM2) shows a quite good fit prediction with that of the raw and tectonic uplift corrected coral-based sea level record of Bard et al. (1996). Peltier (1998) stated that correction for the rate of tectonic uplift has become a standard in interpreting the postglacial relative sea level variability within the region. However, no model has yet been made available for the peninsula or its adjacent vicinity.

8.4.3 Other factors influencing relative sea level change

Assuming that relative sea level difference between the west and east coasts does exist, inferred from the one sea level index point from Kuantan and the estimated relative sea level difference as shown in Fig. 8.4, the discrepancy between the west and east coasts is explained probably caused by combination of the hydro-isostatic and tectonic effects. Due to the inherent limitation posed by other factors, which may similarly affects relative sea level changes, like sediment compaction and consolidation, paleo-tidal changes and the indicative meanings of different sea level index points, their discussions are much restricted.

The hydro-isostatic effect contributed from the imbalance of water masses between Kelang and Kuantan, respectively fronting the Strait of Malacca and the South China Sea, presumably causes the uplift of the former while sinks in the latter. The narrow passage (width from about 70 km in the SE to 300 km in the NW) and shallowness (depth from about <50 m in the SE to ≤100 m in the NW) of the Strait of Malacca means a smaller volume of water and thus of the weight induced, as compared the South China Sea, which contributes to the lower sea level altitude of

Kuantan than Kelang. In addition, the shallowness of the Strait of Malacca (Voris, 2000), implying dry land until about the beginning of Holocene, was thus 'water-free' and separated from the South China Sea during most of the glacial period. This is deduced from the recorded almost uninterrupted sea level rise, from about 120 m below the present, from the Last Glacial Maximum to around the mid Holocene (Geyh et al., 1979; Chappell and Polach, 1991; Ota and Chappell, 1999; Woodroffe, 2000), the event of which has been correlated with the deep-sea oxygen isotope record (Chappell and Shackleton, 1986; Chappell et al., 1996). The incursion and flooding of the narrow Strait of Malacca waterway during the postglacial sea level rise would obviously induce crustal deformation from the water loading process. However, the nature and magnitude of hydroisostasy is yet to be quantified.

Next, tectonic factors are assumed to also contribute to the discrepancy between the west and east coasts relative sea levels, provided the latter does exist. Presuming this is correct the relative sea level difference could probably be affected by plate tectonics of the region. Southeast Asia forms the southern-most part of the Eurasian plate (Fig. 2.4). It is surrounded to the west and southwest by the India-Australia plate and in the east by complex configuration of the Philippine and Pacific plates. The India-Australia plate is subducting below the Eurasian plate at rate of about 67 mm/year (Demets et al., 1990). The subducting India-Australia plate beneath the Eurasian plate, along the plate boundary west of Sumatra (trending almost parallel with the peninsula west coast about 350 km away), probably contributes to the higher uplift of the west coast of the peninsula as compared to the east coast. In contrast the Philippine and Pacific plates in the east are very much further away. This probable tectonic involvement could be roughly estimated by calculating the rate of sea level fall to the present, presuming that the two sites exhibit a continuous sea level fall from its last dated high (Fig. 8.6). The west coast showed an estimated larger (about twice) falling rate than the east, the former approximately 0.7 mm/year while the latter about 0.3 mm/year These crude estimated rates of sea level fall would thus represent the order of magnitude of the long-term tectonic movement in the west and east coasts of the peninsula, provided the observed mid Holocene highstand assumed a continuous sea level fall to the present, and on the assumption that relative sea level difference between the west and east coast is correct. However, the slight relative sea level difference estimated from the peninsular west and east coasts of respective 0.5 and 0.3 mm/year (the

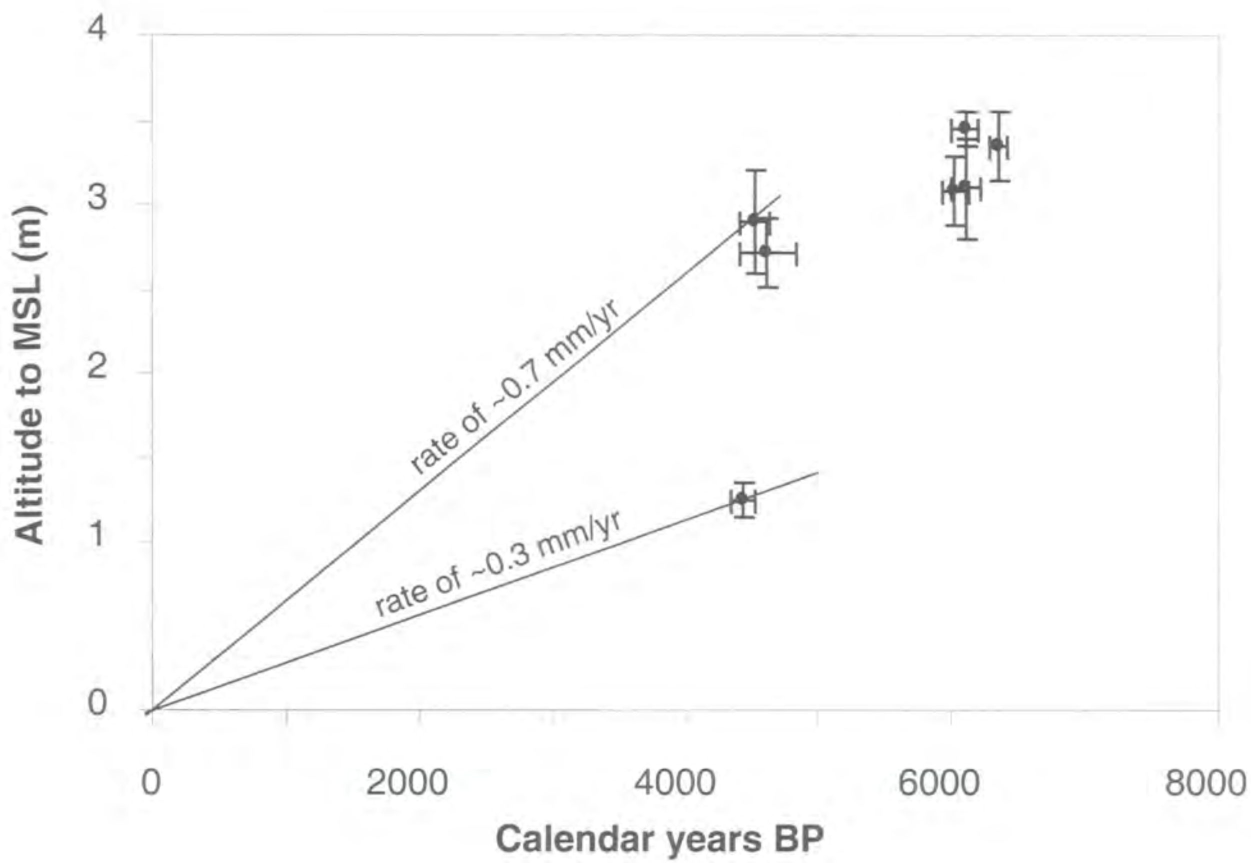


Fig. 8.6 Calculated rate of sea level fall at Kelang and Kuantan.

reassessment of Geyh et al.'s and Tjia's data), as indicated in Fig. 8.4, further points to the explanation of possible crustal deformation. Following these discussions, the postulation of Tjia (1996) of assumed very slow vertical crustal movement of the Sundaland is quite valid, and inferred to maximally range from about 0.3-0.7 mm/year. According to Tjia (1996), Sundaland (comprises peninsular Malaysia, southern Thailand and contiguous areas) is postulated to have experienced only very slow vertical crustal movements at rates 2 to 3 orders lower than the mobile regions (west Sumatra; Java and the lesser islands; north Sarawak, Sabah and east Kalimantan in Borneo; Celebes; Philippines; etc.), which in places is estimated to reach 10 mm/year. Nevertheless, the conclusiveness of the arguments should be further tested by extending investigations in other parts of the peninsula and the region, around west and east Sumatra, Sarawak and west Kalimantan, and Vietnam.

CHAPTER 9

CONCLUSIONS

9.1 Introduction

This concluding chapter summarises the achievement, limitation and extent in which the initial aims and objectives of the research are met. Suggestions and further recommendations to better understand the Holocene sea level changes in Malaysia and the region are also elaborated.

9.2 Holocene sea level history

This research has successfully accomplished its main aims and objectives. Even though much more work needs to be done to fully attain a detailed picture of the peninsular Malaysia Holocene sea level history, the outcome of this study has undoubtedly paved the way towards the in-depth appreciation of the subject. The sea level index points, crucial in the research, have been successfully identified using the northwest Europe sea level methodology and techniques, particularly that employed in Britain (Tooley 1982b; Shennan, 1982a, 1986b; Shennan et al., 1983, 1995a; Plaasche, 1986b). Although limited index points were recognised, their significance as the Holocene sea level record from peninsular Malaysia could not be more emphasised. As far as this research is concerned, the indicative meaning derived from the contemporary mangrove/swamp environment is the first of its kind to be successfully applied in the determination of sea level index points.

9.2.1 Microfossil techniques

In the study, pollen and diatoms form the main method of analyses. A total of 118 sediment samples were analysed, 84 palynologically and 34 for diatom contents. The viability between the microfossil methods is examined by analysing similar samples, in most cases, both pollen and diatom. Pollen analysis is found the better microfossil technique. Pollen and spores are present in moderate to abundant amounts in both the fossil and contemporary sediments, even though in cases up to five slides were counted to fulfil the 200 grains minimum (land pollen plus *Acrostichum aureum*). Meanwhile, diatoms are moderately to abundantly found only in the contemporary sediments. In the fossil samples, however, significant diatoms are only present in two cores from the Meru transect in Kelang. Even that, the preservation is comparatively not as good as the palynomorphs. Foraminifera is least preferred since it is present in only low amounts in the fossil sediments, and also, its analysis requires larger amount of samples as compared to pollen or diatoms.

The contemporary microfossil results show significant relation of the pollen and diatom distribution with altitude, or the reference water levels. The pollen and diatom assemblages, defined by assemblage zones, show characteristic association with particular tidal zone. In Kelang, from MSL to MHWS, three pollen and two diatom zones are differentiated, whereas in Kuantan, from around MLWS to EHW, two pollen and four diatom zones identified. The Kelang pollen assemblages basically show changes from abundant mangrove/low back mangrove to low mangrove/abundant back mangrove, which is succeeded by low mangrove and back mangrove but predominant inland types at around MHWS level. At the MHWS level very low frequency tidal inundation is indicated (daily inundation only 1-2%). Similarly, the diatoms show predominating polyhalobous and planktonics succeeded by predominant mesohalobous and episammic taxa, reflecting change from marine to brackish conditions up the tidal frame. In Kuantan, the pollen assemblages generally show predominant mangrove low back mangrove from MLWS to about ¾(MHWS to EHW) levels, succeeded by predominant coastal freshwater with low mangrove and back mangrove assemblages at around the EHW. The diatoms, meanwhile, exhibit better segregation from the MLWS to about ¾(MHWS to EHW), from predominant polyhalobous and planktonic to predominating mesohalobous with associated abundant tychoplanktonic and epipelic to increased aerophilic assemblages, indicating association from strong marine affinity to brackish and to less frequent inundation. At around the EHW the diatom is almost completely dominated by the oligohalobous indifferent with abundant epipelic and aerophilic taxa pointing to minimum tidal influence.

The study has indicated that the Kelang contemporary microfossil profile could be better improved if the sampling gaps at the levels from MHWN to ½(MHWN to MHWS) and MHWS to EHW are represented. These levels constitute an important segment of the tidal section where the indicative range is related to, but are inconceivably not sampled due to the limitation posed by the contemporary environment, in this case, hindered by the man-made embankment. This has lessened the resolution of the indicative meaning, since an equivalent larger indicative range has to be approximated, especially when the fossil sequence is presumed to correlate within the unrepresentative interval. On the other hand, the Kuantan contemporary profile shows a tidier sampling distribution, thus better microfossil representation within the tidal frame, from about MLWS to EHW. Even so, additional data around ¾(MHWS to EHW) to EHW would increase the resolution better.

9.2.2 Sea level index points

Seven sea level index points are identified from the study area. Six are from Kelang in the west coast and one from Kuantan in the east. These index points are derived from the intercalated peat and clastic sequences, delineated from the stratigraphy. The peat clastic contacts were rigorously analysed biostratigraphically. Microfossil analyses of the sea level indicator samples reveal biostratigraphic change from marine to terrestrial conditions. In the east coast not much is known as regard the biostratigraphy, thus the lesser number of sea level indicator samples from the Kuantan site. The significance of microfossil study is manifested when one of the two Kuantan samples (the two are representatives of different transects) is proven terrestrial in origin even though characteristic intercalated peat and clastic sequences are displayed. The study too, forms a pioneering test on the applicability of the sea level research in the area. In all the Kelang cores, regressive contacts are indicated. The seven index points recognised, all exhibit a negative tendency of sea level movement, implying movement of marine influence away from the site. The indicative meanings of the sea level index points are determined by interpreting its altitudinal relationship with the contemporary environments and related reference tide level. The indicative meaning is not a constant value but varies according to the accuracy of the interpreted indicative range.

9.2.3 Sea level history and its implications

The dates of the index points show concentration of age around the mid Holocene. The plots of relative sea levels from the two contrasting study sites indicate higher than present sea levels but that from Kelang is approximately 1.5 m higher than in Kuantan. Since there is only one sea level index point from Kuantan, the significance and interpretation of the relative sea level difference has to be treated with caution. The result if conclusive, subject to further works, is found to confirm but also contradict the many established postulations regarding mid Holocene high sea level and crustal stability of the peninsula and the region. The mid Holocene high, agrees with the general finding within the peninsula by Tjia (1970, 1980, 1992, 1996), Tjia et al. (1977), Geyh et al. (1979) and Streif (1979), and in the region, from Thailand (Sinsakul et al., 1985; Sinsakul, 1992), Singapore (Hesp et al., 1998) and Indonesia (Hantoro, 1997). Nevertheless, the sea level index points for all the cited references need to be corrected, particularly concerning the indicative meaning.

The mid Holocene high sea level disagrees the geophysical model of Clark et al. (1978), which classifies peninsular Malaysia within the 'zone IV-oceanic submergence' form of postglacial relative sea level curve, with no emerged beaches but dominant submergence. Whether the presumed sea level difference between Kelang and Kuantan is related to differential crustal movement or mere age/altitude variability inherent in the index points, it is clear that more sea level index points are required from Kuantan to ascertain the finding. On the observed estimated relative sea level difference of 0.3 and 0.5 mm/year for the east and west coasts respectively and the presumed discrepancy of 1.5 m applies, suggestions of hydro- and tectono-isostasy are put forward to explain the differential crustal movement between the west and east coasts. The imbalance water masses of the west and east coasts may contribute to differential uplift between the sites. The presumable contribution of plate tectonics due to the subducting India-Australia plate beneath the Eurasian plate, along the plate boundary west of Sumatra, may probably add to the higher uplift of the west coasts of the peninsula as compared to the east. Differential crustal movement at presumed maximal rates of 0.7 mm/year for the west and 0.3 mm/year in the east coasts are inferred. Nevertheless, the possible contribution of other factors that affects relative sea level changes like sediment compaction and consolidation, paleo-tidal changes and the indicative meanings of different sea level index points could not be ruled out.

9.3 Further work

To better illustrate and clarify the findings of this research further work is suggested. This includes:

(i). To provide additional data for the gaps in the Kelang contemporary microfossil profile, at levels from MHWN to ½(MHWN to MHWS) and MHWS to EHW. Concerning the sea level index points, many more should be identified for the Kuantan area, whereas in Kelang, the gap in ages between 4000-5000 BP should be investigated, while from 4000 BP to the present, more data is needed.

(ii). To investigate Holocene coastal sites throughout peninsular Malaysia. The suggestion is to sample the peat clastic contacts, if possible, from as many coastal locations in the peninsula. From biostratigraphy and radiocarbon dating it will enable the determination of the sea level index points. The relative sea level changes between the local areas and the region could then be established.

(iii). To study the coastal contemporary ecological environments from other sites in the west as well the east coasts of the peninsula. The sites for the surface sampling should be chosen from, as best possible, the undeveloped or 'undisturbed' ecological locations so to secure the natural environmental setting. Surface sampling should be taken at equal height interval, with recommended altitudinal spacing of about 10-20 cm. The samples should at least represent the tidal levels from around MSL to EHW.

(iv). To develop 'transfer function', on the relation between contemporary microfossil assemblages (for now, suffice the pollen) with altitude or tidal levels. This would enable the quantification of indicative meaning without the need to investigate the local contemporary environments since their analyses are vital for interpreting the sea level index points. More contemporary environments, as indicated in (iii), should be investigated of their microfossil and probably other environmental variables too (e.g. pH, salinity, substrate and vegetation cover). Zong and Horton (1999) and Horton et al. (1999)

successfully developed respective diatom- and foraminiferal- based transfer function for sea level studies in the UK.

(v). To carry out works, of (ii) and (iii), at other locations in the region. The specific areas selected include, west and east Sumatra, west Kalimantan, Sarawak, Laos and Vietnam. This is to check the probable tectonic involvement in relative sea level changes in the region.

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Appendix 1

Borehole description

1.1 KEC1
Site: Meru, Klang
Date: 26/7/98
Time: 9.20-10.45 am

Author: Kamaludin
Corer type: Peat auger
Ground altitude: 5.404 m MSL
Grid reference: vJ 852491
Ground water level: 124 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.404	0-26	Peat; $Ld^4 3$, Sh1; 2.5YR2/1 (reddish black)	4	0	3	1	0
5.144	26-38	Peat, abundant roots; $Ld^4 3$, Sh1; 2.5YR2/1 (reddish bl.)	4	0	3	1	0
5.024	38-66	Peat; $Ld^4 3$, Sh1, Tl+; 2.5YR2/1 (red. bl.)	4	0	2	1	0
4.744	66-83	Peat; $Ld^4 3$, Sh1, Tl+; 2.5YR1.7/1 (red. bl.)	4	0	2	1	2
4.574	83-87	Root?/Stem; $Tl^0 4$; 2.5YR5/8 (bright brown)	3	0	2	2	2
4.534	87-110	Peat; $Tl^4 1$, Sh1, Dh1, $Ld^4 1$; 2.5YR3/3 (dark red. brown)	4	1	2	2	0
4.304	110-220	Silt, clayey, sandy, humic; Ag2, As1, Gmin1, Ld^3+,Tl^3+; 2.5Y5/1 (yellowish gray) to 5Y5/1 (gray)	2	0	2	0	0
3.204	220-467	Silt, clayey, sandy, humic; Ag3, As1, Gmin+, Ld^3+, Tl^3+, Sh+; 5Y5/1 (gray)	2	0	2	0	0
0.734	467-488	Sand, clayey, silty, humic; Gmin3, Ag1, As+, Tl^3+, Ld^3+; 5Y5/1 (gray)	2	0	2	0	0
0.524	488-492	Silt,clayey, sandy, humic; Ag2, As1, Gmin1, Ld^3+, Tl^3+; 5Y5/1 (gray)	2	0	2	0	0
0.484	492-517	Sand, clayey, silty, humic; Gmin3, Ag1, As+, Tl^3+, Ld^3+; 5Y5/1 (gray)	2	0	2	0	0
0.234	517-536	Silt, sandy, humic; Ag2, Gmin2, Tl^3+, Ld^3+; 5Y5/1 (gray)	2	0	2	0	0
0.044	536-546	Sand, silty, humic; Gmin3, Ag1, Tl^3+, Ld^3+; 5Y5/1 (gray)	2	0	2	0	0
-0.056 to -0.096	546-550	Silt, sandy, humic; Ag3, Gmin1, Tl^3+, Ld^3+; 5Y5/1 (gray); Sandrise, stopped penetration.	2	0	2	0	

1.2 KEC2
Site: Meru, Klang
Date: 26/7/98
Time: 11-12.15 pm

Author: Kamaludin
Corer type: Peat auger 5 m, Guts 8.63 m
Ground altitude: 4.903 m MSL
Grid reference: vJ 846487
Ground water level: 117 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
4.903	0-11	Peat; Sh2, $Ld^4$1, $Tl^4$1; 2.5YR2/1 (reddish black)	4	0	3	1	0
4.793	11-71	Peat; Dg2, $Ld^4$1, $Tl^4$1, Sh+; 2.5YR3/3 (dark reddish brown)	4	0	3	1	1
4.193	71-121	Silt, clayey, humic; Ag3, As1, Ld^4+, Tl^3+; 5Y5/1 (gray)	2	0	2	0	0
3.693	121-131	Silt, clayey, roots, humic; Ag2, As1, $Tl^3$1, Ld^4+;	3	0	2	0	0
3.593	131-170	Silt, clayey, slightly humic; Ag3, As1, Tl^3+, Ld^3+; 7.5GY6/1 (greenish gray)	2	0	2	0	0
3.203	170-614	Silt, clayey, slightly humic; Ag2, As2, Ld^4+; 10GY5/1 (greenish gray)	2	0	2	0	0
-1.237	614-643	Silt, clayey, sandy, some plant remains, slightly humic; Ag2, As1, Gmin1, Ld^4+, Dh+, Dg+; 7.5GY6/1 (greenish gray)	2	0	2	0	0
-1.527 to -3.727	643-863	Sand ($\approx 250\mu$), silty, slightly clayey, some plant remains, slightly humic; Gmin3, Ag1, As+, Dh+, Dg+; 2.5GY6/1 (olive gray); Difficulty, stopped penetration.	2	0	2	0	

1.3 KEC3

Site: Meru, Klang
Date: 26/7/98
Time: 12.35-1.40 pm

Author: Kamaludin
Corer type: Peat auger 0.5 m, Guts 7.42 m
Ground altitude: 4.237 m MSL
Grid reference: vJ 838481
Ground water level: 87 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
4.237	0-24	Peat; $Ld^4$4, Dg+, Sh+; 5YR2/1 (brownish black)	4	0	2	1	1
3.997	24-124	Clay, slightly silty, slightly humic; As4, Ag+, Dg+, Ld^4+; 10YR7/2 (dull yellow orange)	1	0	2	0	0
2.997	124-520	Silt, clayey, slightly sandy, slightly humic; Ag2, As2, Gmin+, Ld^4+, Sh+; 5G5/1 (greenish gray)	2	0	2	0	0
-0.963	520-533	Silt, clayey, sandy, slightly humic; Ag2, As1, Gmin1, Dg+; 5G5/1 (greenish gray)	2	2	2	0	0
-1.093	533-553	Silt, clayey, sandy, mod. plant fragments; Ag2, Gmin1, Dl1, Dh+, Dg+; 5G5/1 (greenish gray)	2	0	2	0	0
-1.293	553-564	Silt, clayey, with thin (mm) sand layers; Ag2, Gmin1, As1, Dg+; 5G5/1 (greenish gray)	2	1	2	0	0
-1.403	564-609	Silt, clayey, very slightly humic; Ag3, As1, Dg+; 5G5/1 (greenish gray)	2	0	2	0	0
-1.853 to -3.183	609-742	Sand (250-400μ), silty, slightly humic; Gmin3, Ag1, Dg+; 10Y6/1 (gray) Difficulty, stopped penetration.	2	0	2	0	

1.4 KEC4
Site: Meru, Klang
Date: 30/7/98
Time: 3.25-5 pm

Author: Kamaludin
Corer type: Edelman 0.5 m, Guts 10.46 m
Ground altitude: 3.787 m MSL
Grid reference: vJ 831474
Ground water level: 50 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.787	0-15	Disturbed (Infilled)					
3.637	15-58	Silt, clayey, very humic, organic; Ag2, As2, Sh+, Ld^3+; 7.5YR5/3 (dull brown) some 10YR6/8 (bright yellowish brown) mottling-probably along root channels	3	0	2	0	0
3.207	58-147	Silt, clayey, some roots, humic; Ag2, As2, Sh+, Dg+; 2.5Y6/1 (yellowish gray)	2	0	2	0	0
2.317	147-154	Wood, silty, clayey; Dl4, Ag+, As+; 2.5YR2/2 (very dark reddish brown)	3	0	2	1	0
2.247	154-427	Silt, clayey, some plant remains, slightly humic; Ag2, As2, Dl+, Dh+, Ld^3+; 2.5Y5/1 (yellowish gray)	2	0	2	0	0
-0.483	427-526	Silt, clayey, slightly humic; Ag3, As1, Dl+, Dg+; 10Y6/1 (gray)	2	0	2	0	0
-1.437	526-535	Silt, clayey; Ag3, As1; 10GY5/1 (greenish gray)	2	0	2	0	1
-1.563	535-638	Silt, clayey, humic, some plant remains; Ag3, As1, Ld^4+, Dg+, Dl+; 5GY6/1 (olive gray)	2	0	2	0	1
-2.593	638-988	Silt, clayey, slightly humic; Ag3, As1, Ld^4+, Dg+, Sh+; 10GY5/1 (greenish gray)	2	0	2	0	0
-6.093	988-997	Clay; As4; N7/0 (grayish white)	2	0	2	0	0
-6.183 to -6.673	997-1046	Clay; As4; ≈30% N7/0 (grayish white) mottling: ≈40% 2.5YR4/6 (reddish brown) ≈30% 2.5Y7/8 (yellow) Difficulty, stopped penetration.	2	0	2	0	

1.5 KEC5
Site: Meru, Klang
Date: 31/7/98
Time: 7.50-10 am

Author: Kamaludin
Corer type: Guts 11.74 m
Ground altitude: 4.070 m MSL
Grid reference: vJ 821473
Ground water level: 33 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
4.070	0-35	Silt, clayey, peaty; Ag2, As1, Sh1, Dg+, Ld^4+; 7.5YR2/3 (very dark brown)	4	0	3	0	0
3.720	35-55	Silt, clayey, humic, some fresh roots; Ag2, As2, Sh+, Ld^4+; 10YR5/4 (dull yellowish brown)	3	0	2	0	0
3.520	55-326	Silt, clayey, some plant remains; Ag3, As1, Dl+, Dg+, Dh+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
0.810	326-330	Wood, silty; $Tl^3$3, Ag1, Ld^3+; 7.5YR4/6 (brown)	3	2	2	1	1
0.770	330-437	Silt, clayey, some plant remains, slightly humic; Ag3, As1, Dl+, Dg+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
-0.300	437-613	Silt, clayey, slightly humic; Ag3, As1, Dg+, Ld^3+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
-2.060	613-746	Silt, clayey, some plant remains, humic; Ag3, As1, Dl+, Dg+, Ld^3+, Tl^3+; 10Y5/1 (gray)	2	0	2	0	0
-3.390	746-1096	Silt, clayey, slightly humic; Ag3, As1, Ld^3+, Sh+; 10Y6/1 (gray)	2	0	2	0	2
-6.890	1096-1098	Sand, silty; Gmin3, Ag3; 7.5GY4/1 (greenish gray)	2	0	2	0	1
-6.910	1098-1161	Silt, clayey, rare humic; Ag3, As1, Sh+; 5GY6/1 (olive gray)	2	0	2	0	0
-7.540 to -7.670	1161-1174	Clay; As4; ≈50% 2.5Y8/1 (light gray) mottling: ≈30% 2.5YR4/6 (reddish brown) ≈20% 7.5YR6/8 (orange) Difficulty, stopped penetration.	2	0	2	0	

1.6 KEC6
Site: Meru, Klang
Date: 31/7/98
Time: 3-5 pm

Author: Kamaludin
Corer type: Peat auger 0.5 m, Guts 15 m
Ground altitude: 3.085 m MSL
Grid reference: vJ 818473
Ground water level: 59cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.085	0-21	Silt, peaty, very humic, fresh roots; Ag2, Sh1, Ld^4+, Dg+, Th^0+; 10R1.7/1 (reddish black)	4	0	4	1	0
2.875	21-79	Clay, silty, humic, some plant remains; As3, Ag1, Sh+, Dg+, Tl^0+; 10YR6/3 (dull yellow orange)	3	0	2	0	0
2.295	79-227	Silt, clayey, slightly humic, some plant remains, some fine sand (≈200μ) along root channels; Ag3, As1, Dl+, Dg+, Dh+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
0.815	227-433	Silt, clayey, slightly humic, some very fine sand in patches; Ag3, As1, Gmin+, Dg+, Ld^3+; 7.5GY5/1 (greenish gray) (Sand as <2 mm thick layerings, dispersed/scattered thro'out the sequence)	2	0	2	0	0
-1.245	433-722	Silt, clayey, rare fine sand, slightly humic; Ag3, As1, Gmin+, Dl+, Dg+, Ld^3+; 10GY5/1 (greenish gray)	2	0	2	0	0
-4.135 to -11.915	722-1500	Silt, clayey, rare very fine sand in patches, slightly humic; Ag3, As1, Gmin+, Ld^3+; 10G6/1 (greenish gray) (The otherwise homogenous lithology is interrupted with thin layers of fine sand at depths 1167-1168, 1176-1177, 1179-1180 cm, and 5 cm of fine sand layer at 1424-1429 cm) Difficulty, stopped penetration.	2	0	2	0	

1.7 KEC7

Site: Mardi, Klang
Date: 2/8/98
Time: 8.55-11.45 am

Author: Kamaludin
Corer type: Peat auger 3 m, Guts 11.70 m
Ground altitude: 5.497 m MSL
Grid reference: vJ 893308
Ground water level: 124 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.497	0-13	Soil development: peaty, silty; Ag2, Dg1, $Tl^4$1, Sh+, Dh+; 5YR1.7/1 (black)	4	0	4	1	0
5.367	13-71	Peat, woody; $Tl^3$2, Dh1, Dg1, Dl+, $Ld^3$1, Sh+; 5YR3/3 (dark reddish brown)	3	0	2	1	1
4.787	71-105	Silt, clayey, slightly humic, some plant remains; Ag2, As2, Ld^3+, Tl^3+; 5Y6/2 (grayish olive)	2	0	2	0	0
4.447	105-381	Silt, clayey, very slightly sandy (≈150μ), humic, some plant remains; Ag2, As2, Gmin+, Dl+, Dg+, Tl^3+, Th^3+; 10Y6/1 (gray)	2	0	2	0	0
1.687	381-700	Silt, clayey, rare fine sand, slightly humic; Ag3, As1, Gmin+, Sh+, Dg+, Dl+, Dh+; 7.5GY5/1 (greenish gray) (The fine sand associated with plant remains)	2	0	2	0	0
-1.503 to -6.203	700-1170	Silt, clayey, slightly sandy (≈100μ), slightly humic; Ag3, As1, Gmin+, Sh+, Dg+; 7.5GY5/1 (greenish gray) Note: The humic matter occurrences seem concentrated in thin mm layerings. Sand occurring as thin patches/layerings <2 mm thick. Difficulty, stopped penetration.	2	0	2	0	

1.8 KEC8

Site: Mardi, Klang
Date: 1/8/98
Time: 11.30-1.45 pm

Author: Kamaludin
Corer type: Peat auger 7 m, Guts
Ground altitude: 6.435 m MSL
Grid reference: vJ 889307
Ground water level: 47 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
6.435	0-13	Peat, slightly silty; Dg2, Tl^{3}1, Sh1, Dl+, Th^3+; 2.5YR2/2 (very dark reddish brown)	4	0	2	1	0
6.305	13-83	Peat; Dg3, Dl1, Ld^4+, Sh+, Tl^3+; 5YR2/2 (brownish black)	3	0	1	2	0
5.605	83-176	Peat; Dg3, Dl1, Sh+, Tl^3+; 2.5YR2/3 (very dark reddish brown)	3	0	1	1	0
4.675	176-214	Silt, clayey, woody, very humic; Ag2, As1, Dl1, Dh+, Dg+; 7.5YR4/2 (grayish brown)	2	0	1	0	2
4.295	214-220	Wood; Tl^{3}4; 5YR4/6 (reddish brown)	3	0	1	2	1
4.235	220-446	Silt, clayey, slightly sandy (≈150μ), some plant remains, very humic; Ag3, As1, Gmin+, Sh+,Tl^3+, Dl+, Dg+; 5Y5/1 (gray)	2	0	1	0	0
1.975	446-1146	Silt, clayey, some plant remains, slightly humic; Ag3, As1, Sh+,Th^3+, Dh+, Dl+, Dg+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
-5.025	1146-1226	Silt, clayey, slightly sandy (≈150μ), some plant remains, humic; Ag3, As1, Gmin+, Dl+, Dg+, Sh+; 10Y6/1 (gray)	2	0	2	0	0
-5.825	1226-1262	Clay, silty; As3, Ag1; N7/0 (grayish white)	1	0	2	0	0
-6.185 to -6.455	1262-1289	Clay; As4; 10Y8/1 (light gray) mottling: ≈3% 10YR6/8 (bright yellowish brown) ≈2% 2.5YR4/6 (reddish brown) Difficulty, stopped penetration.	1	0	2	0	

1.9 KEC9

Site: Mardi, Klang
Date: 3/8/98
Time: 9.05-10.55 am

Author: Kamaludin
Corer type: Peat auger 6 m, Guts
Ground altitude: 6.846 m MSL
Grid reference: vJ 887306
Ground water level: 35 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
6.846	0-3	Infilled					
6.816	3-35	Peat; Dg1, $Ld^4$1, Sh1, $Tl^4$1, Dl+; 10R2/1 (reddish black)	4	0	2	1	0
6.496	35-191	Peat; Dg1, $Ld^3$1, $Tl^3$1, Dl1, Sh+, Th^3+; 2.5YR2/3 (very dark reddish brown)	3	0	1	1	1
4.936	191-220	Silt, clayey, slightly sandy (≤5%), very humic, mod. amount of plant remains; Ag2, As1, Dg1, Gmin+, Dh+,Tl^3+, Th^3+; 10YR6/3 (dull yellow orange) (Sand occurring with the plant remains)	2	0	2	0	0
4.646	220-463	Silt, clayey, slightly sandy (≤5%), humic, mod. amount of plant remains; Ag2, As1, Dg1, Gmin+, Dh+, Dl+, Tl^3+, Ld^3+; 10Y5/1 (gray) (Sand occurring with the plant remains)	2	0	2	0	0
2.216 to -5.364	463-1221	Silt, clayey, some plant remains, humic; Ag3, As1, Ld^3+, Dl+, Dg+; 7.5GY5/1 (greenish gray) Thro'out the sequence rather homogenous, only the minor components showed some changes: 6-7 m, Dl+ absent, 7-12.21 m, Dh+ present, Difficulty, stopped penetration.	2	0	2	0	

1.10 KEC10
Site: Mardi, Klang
Date: 1/8/98
Time: 8.45-10.40 am

Author: Kamaludin
Corer type: Peat auger 0-4 &5-7 m, Guts 4-5 & 7-11 m
Ground altitude: 7.097 m MSL
Grid reference: vJ 885307
Ground water level: 37 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
7.097	0-5	Peat; Dg1, Dh1, Dl1, $Tl^3$1; 2.5YR2/1 (reddish black)	4	0	3	2	0
7.047	5-109	Peat, silty; Ag1, Dg1, Dl1, $Tl^3$1 Dh+; 2.5YR2/3 (very dark reddish bl.)	4	0	2	1	0
6.007	109-125	Peat, very woody; $Tl^3$3, Dg1, Dl+; 2.5YR3/6 (dark reddish brown)	3	0	1	1	0
5.847	125-220	Peat; $Tl^3$2, Dl1, Dg1, Ld^3+; 2.5YR1.2/3 (very dark reddish brown)	3	0	1	1	0
4.897	220-232	Peat, very woody; $Tl^3$3, Dl1, Dg+, Ld^3+; 2.5YR4/6 (reddish brown)	3	0	1	2	0
4.777	232-241	Peat; $Tl^3$2, Dg1, Dl1, Ld^3+; 2.5YR2/2 (very dark reddish brown)	4	0	1	1	1
4.687	241-314	Silt, clayey, slightly sandy, small amount of plant remains, roots, humic; Ag2, As1, Dg1, Gmin+, Dl+, Ld^3+,Th^3+; 10YR5/3 (dull yellowish brown)	3	0	1	0	2
3.957	314-316	Wood; $Tl^3$4; 2.5YR2/4 (very dark reddish brown)	2	0	2	0	0
3.937	316-400	Silt, clayey, slightly sandy, humic, small amount of plant remains; Ag3, As1, Gmin+, Dl+, Dg+, Tl^3+, Sh+; 5Y5/1 (gray)	2	0	1	0	
3.097	400-642	Sample not recovered					
0.677	642-856	Silt, clayey, slightly sandy, humic, small amount of plant remains; Ag3, As1, Gmin+, Dl+, Dg+, Tl^3+, Sh+; 5Y5/1 (gray)	2	0	2	0	0
-1.463	856-1000	Silt, clayey, slightly humic, some plant remains; Ag3, As1, Dl+, Dg+; 10Y6/1 (gray)	2	0	2	0	0
-2.903 to -3.903	1000-1100	Silt, clayey, rare sand, humic, some plant remains; Ag3, As1, Gmin+, Dl+, Dg+, Tl^3+; 10Y5/1 (gray) Difficulty, stopped penetration (the guts is lost while trying to go to 12 m).	2	0	2	0	

1.11 KEC11
Site: Mardi, Klang
Date: 3/8/98
Time: 12.20-2 pm

Author: Kamaludin
Corer type: Peat auger 6 m, Guts
Ground altitude: 4.928 m MSL
Grid reference: vJ 895311
Ground water level: 39 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
4.928	0-7	Infilled					
4.858	7-14	Peat; Dg1, $Ld^4$1, Sh1, $Tl^4$1, Dl+; 10R2/1 (reddish black)	3	0	2	1	0
4.788	14-27	Silt, clayey, very humic, some plant remains; Ag2, As1, Dg1, Dh+, Dl+Tl^3+; 10YR6/2 (grayish yellow brown) (Sand occurring with the plant remains)	2	0	2	0	0
4.658	27-278	Silt, clayey, rare sand, humic, some plant remains; Ag2, As2, Dg+, Gmin+, Dh+, Dl+, Th^3+; 7.5Y6/1 (gray) (Sand along roots, stems, trunks)	2	0	2	0	0
2.148	278-475	Silt, clayey, slightly humic, some plant remains; Ag3, As1, Dg+, Dl+, Tl^3+, Ld^3+; 10Y5/1 (gray)	2	0	2	0	0
0.178 to -6.422	475-1135	Silt, clayey, some plant remains, slightly humic; Ag3, As1, Ld^3+, Dl+, Dg+; 7.5GY5/1 (olive gray) (Thro'out the sequence rather homogenous) Difficulty, stopped penetration.	2	0	2	0	

1.12 KEC12

Site: Mardi, Klang
Date: 2/8/98
Time: 2.30-3.40 pm

Author: Kamaludin
Corer type: Peat auger 6.5 m, Guts
Ground altitude: 5.774 m MSL
Grid reference: vJ 899310
Ground water level: 68 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.774	0-13	Infilled					
5.644	13-29	Peat; $Tl^4$2, Dl1, Dg1, Ld^4+; 5YR2/1 (brownish black)	4	0	3	2	0
5.484	29-118	Peat; $Tl^3$1, Dl1, Dg1, Sh1, Ld^3+; 2.5YR2/1 (reddish black)	3	0	1	2	1
4.594	118-130	Silt, clayey, slightly sandy, very humic, plant remains; Ag2, As2, Gmin+, Sh+, Dl+, Dg+, Tl^3+; 7.5YR4/3 (brown)	2	0	1	0	1
4.474	130-134	Wood; $Tl^3$4, Sh+; 5YR4/8 (reddish brown)	3	0	1	1	1
4.434	134-585	Silt, clayey, slightly sandy (≈350μ), very humic, plant remains; Ag3, As1, Gmin+, Sh+, Dl+, Dg+, Tl^3+; 2.5Y5/1 (yellowish gray)	2	0	1	0	1
-0.076	585-591	Sand (≈400-450μ), silty, slightly humic, rare plant remains; Gmin2, Ag1, As1, Sh+, Dg+; 5Y6/1 (gray)	2	0	2	0	1
-0.136	591-595	Silt, clayey, slightly sandy (≈350μ), very humic, plant remains; Ag3, As1, Gmin+, Sh+, Dl+, Dg+, Tl^3+; 2.5Y5/1 (yellowish gray)	2	0	1	0	1
-0.176 to -0.726	595-650	Sand (500-1400μ), silty, slightly humic; Gmin3, Ag1, Sh+, Dg+; 5Y6/1 (gray) Sandrise, stopped penetration.	2	0	1	0	

1.13 KEC13
Site: Mardi, Klang
Date: 2/8/98
Time: 12.45-2.15 pm

Author: Kamaludin
Corer type: Peat auger 4.80 m, Guts
Ground altitude: 5.698 m MSL
Grid reference: vJ 904310
Ground water level: 61 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.698	0-96	Peat; $Tl^4 1$, Dl1, Dg1, $Ld^4 1$, Dh+; 2.5YR5/2 (very dark reddish brown)	4	0	2	0	1
4.738	96-421	Clay, silty, slighty sandy (≈200μ), very humic, plant remains (numerous small fresh roots); As2, Ag1, $Tl^3 1$, Gmin, Dl+, Dg+; 2.5Y5/2 (dark grayish) some 10YR6/8 (bright yellowish brown) mottling-probably along root channels	2	0	2	0	0
1.488	421-527	Clay, silty, slightly humic, some plant remains; As3, Ag1, Dg+, Tl^3+; N7/0 (grayish white) mottling ≈5% red & bright yellowish brown	2	0	1	0	0
0.428 to 0.248	527-545	Clay; As4; ≈55% N8/0 (grayish white) mottling: ≈35% 7.5R3/6 (dark red) ≈10% 7.5YR5/8 (bright brown) Difficulty, stopped penetration.	1	0	1	0	

1.14 KEC14
Site: Mardi, Klang
Date: 4/8/98
Time: 11-2 pm

Author: Kamaludin
Corer type: Peat auger 5.5 m, Guts
Ground altitude: 6.001 m MSL
Grid reference: vJ 907310
Ground water level: 65 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
6.001	0-136	Peat; Dg2, $Ld^3$2, Dl+, Dh+, Tl^4+; 2.5YR2/2 (very dark reddish brown)	4	0	1	1	1
4.641	136-181	Silt, clayey, humic, abundant plant remains; Ag2, As1, Dg1, Dh+, Ld^3+, Tl^3+; 10YR5/2 (grayish yellow brown)	2	0	2	0	0
4.191	181-523	Silt, clayey, rare sand, humic, plant remains; Ag3, As1, Dg+, Dl+, Tl^3+, Th^3+; 10Y6/1 (gray) (showing fibrous structure when split)	2	0	2	0	0
0.771	523-549	Silt, clayey, humic, some plant remains; Ag3, As1, Dg+, Dl+, Ld^3+; Variegated colours: ≈50% 5GY5/1 (olive gray) ≈50% 5Y6/1 (gray)	2	0	2	0	0
0.511	549-560	Clay, silty, some plant remains; As3, Ag1, Dh+, Dg+, Dl+; N7/0 (grayish white)	1	0	2	0	0
0.401 to -0.339	560-634	Clay; As4; N8/0 (grayish white) mottling: ≈20% 10R3/6 (dark red) ≈2-3% 2.5Y6/6 (bright yellowish brown) Difficulty, stopped penetration.	1	0	2	0	

1.15 KUC7

Site: Penor (north), Kuantan
Date: 17/7/98
Time: 8.15-10.30 am

Author: Kamaludin
Corer type: Edelman 3 m, Guts
Ground altitude: 3.866 m MSL
Grid reference: wA870113
Ground water level:

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.866	0-35	Sand (125-250µ), silty, slightly organic; Gmin2, Ag2, Sh+; 10YR4/2 (grayish yellow brown)	3	0	3	0	0
3.516	35-90	Sand (≈200µ), silty, clayey; Gmin2, Ag2, As+; 2.5Y7/2 (grayish yellow) mottled 10YR6/8 (bright yellowish brown)	2	0	3	0	0
2.966	90-125	Silt, sandy (≈100µ), clayey; Ag2, As1, Gmin1; 10YR5/3 (dull yellowish brown)	2	0	2	0	0
2.616	125-170	Sand (≈100µ), silty, clayey; Gmin2, Ag2, As+; 10GY8/1 (light greenish gray)	1	0	3	0	0
2.166	170-195	Sand (≈100µ), silty; Gmin2, Ag2; 5P7/1 (light purplish gray) 20% mottled 10YR7/8 (yellow orange)	1	0	3	0	0
1.916	195-200	Sand (≈150µ), silty; Gmin2, Ag2; 5P7/1 (light purplish gray) mottling: ≈25% 10YR7/8 (yellow orange) ≈25% 2.5YR3/6 (dark reddish brown)	1	0	3	0	0
1.866	200-325	Silt, sandy, clayey; Ag2, Gmin1, As1; 5P7/1 (light purplish gray) mottling: ≈10% 10YR7/8 (yellow orange) ≈5% 2.5YR3/6 (dark reddish brown)	1	0	2	0	0
0.616	325-375	Clay, silty; As3, Ag1; 10Y5/1 (gray)	2	0	2	0	0
0.116	375-445	Silt, clayey, slightly sandy; Ag3, As1, Gmin+; 7.5GY5/1 (greenish gray)	2	0	2	0	0
-0.584	445-465	Sand (≈150µ), silty, clayey; Gmin3, Ag1, As+; 10G5/1 (greenish gray) 10% mottled 2.5YR3/6 (dark reddish brown)	2	0	3	0	1
-0.784	465-480	Clay; As4; 7.5Y6/1 (gray) 80% mottled 2.5YR3/6 (dark reddish brown)	1	0	3	0	0
-0.934 to -1.494	480-536	Clay; As4; 10Y8/1 (light gray) 30-40% mottled 2.5YR3/6 (dark reddish brown) Difficulty, stopped penetration.	1	0	2	0	

1.16 KUC9
Site: Penor (north), Kuantan
Date: 18/7/98
Time: 9.40-11 am

Author: Kamaludin
Corer type: Edelman 3 m, Guts
Ground altitude: 3.515 m MSL
Grid reference: wA864121
Ground water level: 11 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.515	0-5	Infilled					1
3.465	5-48	Peat, clayey, silty; Sh2, Ag1, As1, Tl^3+; 10YR3/4 (dark brown)	4	0	1	1	0
3.035	48-66	Sand (≈450μ), silty, slightly organic; Gmin3, Ag1, Sh+; 10Y4/2 (olive gray)	2	0	1	0	0
2.855	66-115	Peat, silty; Sh3, $Tl^3$1,Ag+; 7.5YR3/4 (dark brown)	4	0	1	1	0
2.365	115-173	Silt, clayey, moderately organic, plant remains; Ag2, As1, Sh1, Tl^3+; 10YR4/2 (grayish yellow brown)	3	0	2	0	0
1.785	173-229	Silt, clayey, slightly humic; Ag2, As2, Sh+, Tl^3+; 5Y4/1 (gray)	2	0	2	0	0
1.225	229-300	Clay, silty; As3, Ag1; 5Y8/2 (light gray) mottling: ≈70% 2.5Y6/6 (bright yellowish brown) ≈5% 7.5R3/6 (dark red)	1	0	2	0	0
0.515 to -0.005	300-352	Clay, slightly silty; As4, Ag+; 10Y8/1 (gray) mottling: ≈10% 2.5Y6/6 (bright yellowish brown) ≈25% 7.5R3/6 (dark red) Difficulty, stopped penetration.	1	0	2	0	

1.17 KUC11
Site: Penor (north), Kuantan
Date: 19/7/98
Time: 8.30-10 am

Author: Kamaludin
Corer type: Peat auger 1 m, Guts
Ground altitude: 3.601 m MSL
Grid reference: wA862127
Ground water level: 18 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.601	0-17	Clay, very peaty, silty; Sh2, As2, Ag+; 7.5YR3/3 (dark brown)	4	0	2	1	0
3.431	17-42	Clay, peaty, sandy; As2, Sh1, Gmin1, Gmaj+; 10YR5/4 (dark brown)	3	0	1	0	0
3.181	42-94	Clay, very peaty, silty; Sh2, As2, Ag+; 7.5YR3/3 (dark brown)	4	0	2	0	0
2.661	94-125	Silt, clayey, peaty; Ag2, Sh1, As1; 10YR3/2 (brownish black)	3	0	2	0	0
2.351	125-150	Silt, woody, clayey, sandy, humic; Ag2, $Tl^1$1, As1, Gmin+; 7.5YR4/2 (grayish brown)	3	0	2	0	0
2.101	150-190	Silt, clayey, humic, plant remains in patches; Ag2, As1, Sh1, Tl^1+; 7.5YR4/2 (grayish brown)	3	0	2	0	0
1.701	190-220	Silt, clayey, humic, decomposed wood; Ag3, As1, Sh+, Tl^1+; 10YR4/1 (brownish gray)	3	0	2	0	0
1.401	220-232	Silt, woody, clayey, slightly humic; Ag2, $Tl^1$1, As1, Sh+; 2.5YR4/1 (yellowish gray)	3	0	2	0	0
1.281	232-243	Clay, silty, sandy, slightly humic; As2, Ag1, Gmin1, Sh+; 2.5Y5/1 (yellowish gray)	2	0	2	0	0
1.171	243-322	Clay, silty; As2, Ag2; 10GY8/1 (light greenish gray) mottling: ≈60% 2.5Y7/6 (bright yellowish brown) ≈10% 10R4/6 (red)	2	0	2	0	0
0.381 to 0.191	322-341	Clay; As4; 10GY8/1 (light greenish gray) mottling: ≈20% 10YR6/8 (bright yellowish brown) ≈30% 7.5R4/8 (red) Difficulty, stopped penetration.	1	0	2	0	

1.18 KUC15

Site: Penor (north), Kuantan
Date: 20/7/98
Time: 8.15-9.30 am

Author: Kamaludin
Corer type: Peat auger 1.5 m, Guts
Ground altitude: 3.514 m MSL
Grid reference: wA865117
Ground water level: 12 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.514	0-20	Infilled					2
3.314	20-45	Peat, clayey, silty $Tl^2$2, Sh1, As1, Ag+; 10YR2/3 (brownish black)	3	0	1	1	1
3.064	45-100	Clay, peaty, silty, sandy; Sh1, As2, $Tl^2$1, Gmin+; 7.5YR2/3 (very dark brown)	3	0	2	0	0
2.514	100-228	Silt, clayey, peaty; Ag3, As1, Sh+, Tl^3+; 7.5YR3/2 (brownish black)	3	0	2	0	0
1.234	228-257	Silt, clayey, very humic; Ag3, As1, Sh+, Tl^3+; 10YR4/3 (dull yellowish brown)	2	0	2	0	0
0.944	257-270	Clay, silty, slightly humic; As2, Ag2, Sh+; 2.5Y6/1 (yellowish gray)	1	0	2	0	0
0.814	270-275	Silt, clayey, humic; Ag2, As2; 2.5Y4/1 (yellowish gray)	2	0	2	0	0
0.764 to -0.086	275-360	Clay, slightly silty; As3, Ag1; 5Y8/2 (light gray) mottling: ≈50% 2.5Y6/6 (bright yellowish brown) ≈10-15% 2.5YR4/6 (reddish brown) Difficulty, stopped penetration.	1	0	2	0	

1.19 KUC16

Site: Penor (north), Kuantan
Date: 20/7/98
Time: 9.50-10.50 am

Author: Kamaludin
Corer type: Peat auger 1.5 m, Guts
Ground altitude: 3.670 m MSL
Grid reference: wA858132
Ground water level: 23 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
3.670	0-26	Infilled					1
3.410	26-48	Clay, silty, peaty; Sh2, As1, $Tl^2$1, Ag+; 7.5YR4/3 (brown)	3	0	2/3	0	0
3.190	48-100	Silt, clayey, very humic; Ag2, Sh1, $Tl^2$1, As+; 10YR4/4 (brown)	3	0	2	0	0
2.670	100-142	Clay, silty, slightly humic; As3, Ag1, Sh+, Tl^2+; variegated colours: 7.5YR5/1 (brownish gray) 2.5Y7/1 (light gray)	2	0	2	0	0
2.250	142-192	Clay, silty, sandy; As2, Ag1, Gmin1; N8/0 (grayish white) 30% mottled 2.5Y5/6 (yellowish brown)	1	0	2	0	0
1.750 to 0.790	192-288	Clay, silty, rare sand; As2, Ag2, Gmin+; N8/0 (grayish white) mottling: ≈20-30% 2.5Y6/8 (bright yellowish brown) ≈10% 10R4/8 (red) Difficulty, stopped penetration.	1	0	2	0	

1.20 KUC12

Site: Penor (south), Kuantan
Date: 19/7/98
Time: 10.30-11.30 am

Author: Kamaludin
Corer type: Peat auger 2 m, Guts
Ground altitude: 5.685 m MSL
Grid reference: wA886063
Ground water level: 9 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.685	0-40	Infilled					1
5.285	40-57	Clay, peaty, sandy; As2, Sh1, Gmin1, Gmaj+; 10YR5/4 (dark brown)	1	0	2	0	0
5.115	57-59	Silt, sandy, humic; Ag2, Gmin2, Sh+, Tl^2+; 10YR4/2 (grayish yellow brown)	2	0	2	0	1
5.095	59-162	Peat; $Tl^2$4, Sh+; 2.5YR2/2 (reddish black)	4	0	1	2	0
4.065	162-178	Peat, silty; $Tl^3$2, Ag1, Sh1; 10YR1.7/1 (black)	4	0	1	0	0
3.905	178-188	Silt, clayey, peaty; Ag3, Sh1, Tl^2+; 7.5YR2/3 (very dark brown)	3	0	2	0	0
3.805	188-227	Silt, clayey, sandy, humic; Ag3, Gmin1, As+, Sh+; 7.5YR4/4 (brown)	3	0	2	0	0
3.415 to 2.785	227-290	Silt, clayey, sandy; Ag2, As1, Gmin1; 5Y7/2 (light gray) Difficulty, stopped penetration.	1	0	2	0	

1.21 KUC13

Site: Penor (south), Kuantan
Date: 19/7/98
Time: 11.35-12.30 pm

Author: Kamaludin
Corer type: Peat auger 1.5 m, Guts
Ground altitude: 5.570 m MSL
Grid reference: wA888059
Ground water level: 13 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.570	0-24	Infilled					1
5.330	24-36	Sand (500-700μ), silty, humic; Gmin3, Sh1, Ag+; 5Y6/2 (grayish olive)	2	0	2	0	0
5.210	36-63	Silt, sandy, humic, roots; Ag2, Gmin1, Sh1, Tl^2+; 2.5Y4/1 (yellowish gray)	2	0	2	0	0
4.940	63-116	Peat; $Tl^3$4, Sh+; 2.5YR2/4 (very dark reddish brown)	4	0	1	2	0
4.410	116-136	Peat, clayey; Sh3, $Tl^3$1, As+; 5YR2/2 (brownish black)	4	0	1	1	0
4.210	136-144	Wood; $Tl^1$4, Sh+; 7.5YR5/8 (bright brown)					1
4.130	144-168	Silt, clayey, very humic, some roots; Sh3, Ag1, As+; 7.5YR1.7/1 (black)	4	0	2	0	0
3.890	168-237	Clay, sandy (500-2000μ), silty; As2, Gmin1, Ag1; 5Y7/2 (light gray)	1	0	2	0	
3.200 to 2.920	237-265	No recovery Difficulty, stopped penetration.					

1.22 KUC14

Site: Penor (south), Kuantan
Date: 19/7/98
Time: 12.40-1.35 pm

Author: Kamaludin
Corer type: Edelman 20 cm & 1.5-2.2 m, Peat auger 20 cm to 1.5 m
Ground altitude: 5.338 m MSL
Grid reference: wA889054
Ground water level: 85 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.338	0-14	Infilled					1
5.198	14-48	Peat; $Tl^3$4, Sh+; 5YR2/2 (brownish black)	4	0	1	1	0
4.858	48-62	Peat, clayey; $Tl^3$3, Sh1, As+; 2.5YR2/2 (very dark reddish brown)	4	0	2	0	0
4.718	62-79	Clay, silty, sandy, peaty; As2, Ag1, Sh1, Gmin+, Tl^3+; 7.5YR3/3 (dark brown)	3	0	2	0	0
4.548	79-85	Silt, clayey, sandy, humic, plant & roots; Sh1, Ag1, As1, Gmin1, Tl^3+; 10YR5/4 (dull yellowish brown)	3	0	2	0	0
4.488	85-98	Silt, clayey, sandy, slightly humic; Ag2, As1, Gmin1, Sh+, Tl^2+; 2.5Y5/1 (yellowish gray)	2	0	2	0	0
4.358	98-170	Clay, silty, sandy; As2, Gmin1, Ag1, Gmaj.+; 2.5Y7/1 (light gray)	1	0	2	0	0
3.638 to 3.138	170-220	Clay, sandy; As2, Gmin2, Gmaj.+; 2.5Y7/1 (light gray) Difficulty, stopped penetration.	1	0	2	0	

1.23 KUC17

Site: Penor (south), Kuantan
Date: 20/7/98
Time: 11.30-12.25 am

Author: Kamaludin
Corer type: Peat auger 1.5 m, Guts
Ground altitude: 5.984 m MSL
Grid reference: wA884068
Ground water level: 31 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
5.984	0-38	Infilled					1
5.604	38-47	Silt, sandy, clayey, humic; Ag2, Gmin1, As1, Sh+, Tl^2+; 7.5GY6/1 (greenish gray)	2	0	2	0	0
5.514	47-64	Silt, sandy, humic; Ag2, Gmin2, Sh+; 5Y2/1 (black)	4	0	2	0	2
5.344	64-95	Peat, woody; $Tl^3$3, Sh1; 7.5YR2/2 (brownish black)	4	0	1	0	0
5.034	95-102	Silt, clayey, humic; Ag3, As1, Sh+, Tl^3+; 10YR4/6 (brown)	3	0	2	0	0
4.964	102-160	Clay, silty, slightly humic; As3, Ag1, Sh1, Tl^2+; 2.5Y5/2 (dark grayish)	1	0	2	0	0
4.384 to 3.754	160-223	Clay, slightly silty, sandy; As4, Ag+, Gmin+; 5Y7/1 (light gray) (very stiff) Difficulty, stopped penetration.	1	0	2	0	

1.24 KUC18

Site: Penor (south), Kuantan
Date: 20/7/98
Time: 12.50-1.35 pm

Author: Kamaludin
Corer type: Guts
Ground altitude: 4.881 m MSL
Grid reference: wA891050
Ground water level: 30 cm

Altitude (m)	Depth (cm)	Description & Components	Nig	Strf	Sicc	Elas	Lim sup
4.881	0-16	Infilled					1
4.721	16-19	Silt, sandy, very humic; Sh2, Ag2, Gmin+; 7.5YR2/1 (black)	4	0	1	0	0
4.691	19-31	Silt, sandy, very humic; Ag2, Gmin1, Sh1; mixture of 2 colors: 7.5YR3/3 (dark brown) & 5Y7/3 (light yellow)	3	0	2	0	0
4.571	31-41	Silt, sandy, very humic; Ag2, Gmin1, Sh1; 7.5YR2/1 (black)	4	0	1	0	0
4.471	41-69	Sand, silty, slightly humic; Gmin2, Ag2, Sh+; 10YR4/3 (dull yellowish brown)	3	0	2	0	0
4.191 to 2.501	69-238	Sand (1000-1500μ), clayey, silty; Gmin3, As1, Ag+, Gmaj+; 5Y8/2 (light gray) Difficulty, stopped penetration.	1	0	2	0	

Appendix 2

Sample description and analysis

2.1 Contemporary sample analysis (surface sample)

(Abbreviations used: a=analysed, s=scanned, p=prepared, na=not analysed)
(unless otherwise stated, volume of sediment sample processed is ~0.5ml)

Sampling locations:	Klang (KES) and Kuantan (KUS, KUPS)	
KES1-18:	Kg. Pantai, Jeram, Klang	*Tidal flat to mangrove coast*
KES 19-21:	Pantai Remis, Klang	*Nipa vegetation (dry)*
KUS1-15:	South end of Kuantan-Tg. Lumpur bridge	*Mangrove coast*
KUS16-18:	Near south end of Kuantan-Tg. Lumpur bridge	*Acrostichum aureum and Grasses vegetation (dry)*
KUS19-21:	Near south end of Kuantan-Tg. Lumpur bridge	*Nipa swamp*
KUPS13-15:	Kg. Kuala Penur, Kuantan	*Coastal Pandanus swamp*

Environment: **Tidal flat to mangrove coast**
Sampling location: Kg. Pantai, Jeram, Klang (~ 03°13'33"N & 101°18'21"E, to 388 m WSW)

POLLEN Sample no.	Altitude to MSL (m)	Comments	DIATOM Sample no.	Altitude to MSL (m)	Comments
KES3	-0.095	a (1 slide)	KES3	-0.095	a
KES7	0.138	a (2 slides)	KES7	0.138	a
KES9	0.335	a (1 slide)	KES9	0.335	a
KES11	0.542	a (1 slide)	KES11	0.542	a
KES13	0.74	a (1 slide)	KES13	0.74	a
*KES15	0.926	a (2 slides-few grains)**	KES15	0.926	a
KES16	1.449	a (1 slide)	KES16	1.449	a
*KES17	1.801	a (2 slides)	KES17	1.801	a
*KES18	2.181	a (2 slides)	KES 18	2.181	a

* (Sediment sample volume=2.5ml)
** (Counted only 37 pollen grains from the 2 slides analysed)

Environment: ***Nipa* vegetation (dry)**
Sampling location: Pantai Remis, Klang (~ 03°12'N & 101°18'34"E, to 650 m E)

POLLEN Sample no.	Altitude to MSL (m)	Comments	DIATOM Sample no.	Altitude to MSL (m)	Comments
KES19	1.759	a (1 slide)	KES19	1.759	na
KES20	1.439	a (2 slides)	KES20	1.439	na
KES21	1.927	a (1 slide)	KES21	1.927	na

Environment: **Mangrove coast**
Sampling location: South end of Kuantan-Tg. Lumpur bridge (~ 03°48'12"N & 103°20'06"E, to 125 m NNW)

POLLEN Sample no.	Altitude to MSL (m)	Comments	DIATOM Sample no.	Altitude to MSL (m)	Comments
KUS1	-0.62	a (2 slides)	KUS1	-0.62	a
KUS3	-0.263	a (2 slides)	KUS3	-0.263	a
KUS5	0.147	a (2 1/2 slides)	KUS5	0.147	a
KUS7	0.505	a (2 slides)	KUS7	0.505	a

KUS9	0.723	a (2 slides)	KUS9	0.723	a
KUS11	0.862	a (1 slide)	KUS11	0.862	a
KUS13	0.999	a (1 slide)	KUS13	0.999	a
KUS15	1.334	a (3 slides)	KUS15	1.334	a

Environment: ***Acrostichum aureum* and Grasses vegetation (dry)**

Sampling location: Near south end of Kuantan-Tg. Lumpur bridge (~ 03°48'09"N & 103°20'08"E, to 13 m WSW)

POLLEN			DIATOM		
Sample no.	Altitude to MSL (m)	Comments	Sample no.	Altitude to MSL (m)	Comments
KUS16	1.799	a (1 slide)	KUS16	1.799	a
KUS17	1.777	a (1/2 slide)	KUS17	1.777	a
KUS18	1.465	a (1 1/2 slides)	KUS18	1.465	a

Environment: ***Nipa* swamp**

Sampling location: Near south end of Kuantan-Tg. Lumpur bridge (~ 03º48'02"N & 103º20'18"E, to 36m N)

POLLEN			DIATOM		
Sample no.	Altitude to MSL (m)	Comments	Sample no.	Altitude to MSL (m)	Comments
KUS19	1.1	a (1 1/2 slides)	KUS19	1.1	a
KUS20	1.098	a (1 slide)	KUS20	1.098	a
KUS21	0.709	a (2 slides)	KUS21	0.709	a

Environment: **Coastal *Pandanus* swamp**

Sampling location: Kg. Kuala Penur, Kuantan (~ 03°40'04"N & 103°21'08"E, to 120 m SW)

POLLEN			DIATOM		
Sample no.	Altitude to MSL (m)	Comments	Sample no.	Altitude to MSL (m)	Comments
KUPS13	3.566	a (1/2 slide)	KUPS13	3.566	a
KUPS14	3.74	a (2 slides)	KUPS14	3.74	a
KUPS15	3.756	a (1 slide)	KUPS15	3.756	a

2.2 Fossil (core) sample analysis

(Abbreviations used: a=analysed, s=scanned, p=prepared, na=not analysed)
(unless otherwise stated, volume of sediment sample processed is ~0.5ml)

Sampling locations: Klang (KEC) and Kuantan (KUC)

KEC1,2 :	Meru, Klang	*Oil palm plantation*
KEC7,8,9,13 :	Mardi, Klang	*Oil palm plantation*
KUC15 :	Penor (north), Kuantan	*Freshwater swamp*
KUC12 :	Penor (south), Kuantan	*Freshwater swamp*

Core no.: **KEC1**
Location: Meru, Klang
Geographical co-ord.: 3°09'14"N, 101°27'48"E
Ground altitude: 5.404 m

POLLEN

Depth (cm)	Altitude to MSL (m)	Comments
105	4.354	a (2 slides)
107	4.334	a (5 slides)
109	4.314	a (3 slides)
111	4.294	a (3 slides)
113	4.274	a (3 slides)
116	4.244	a (3 slides)

DIATOM

Depth (cm)	Altitude to MSL (m)	Comments
105	4.354	s (2 slides-Nil)
107	4.334	s (2 slides-Very rare)
109	4.314	s (2 slides-Nil)
111	4.294	a (2 slides)
113	4.274	a (3 slides)
116	4.244	a (3 slides)

Core no.: **KEC2**
Location: Meru, Klang
Geographical co-ord.: 3°09'N, 101°27'30"E
Ground altitude: 4.903 m

POLLEN

Depth (cm)	Altitude to MSL (m)	Comments
66	4.243	a (1 slide)
68	4.223	a (1 slide)
70	4.203	a (2 slides)
71	4.193	a (1 slide)
73	4.173	a (1 slide)
76	4.143	a (2 slides)

DIATOM

Depth (cm)	Altitude to MSL (m)	Comments
66	4.243	s (2 slides-Very rare)
68	4.223	a (2 slides)
70	4.203	a (2 slides)
71	4.193	a (1 slide)
73	4.173	a (1 slide)
76	4.143	a (1 slide)

Core no.: **KEC7**
Location: Mardi, Klang
Geographical co-ord.: 2°59'14"N, 101°29'59"E
Ground altitude: 5.497 m

POLLEN

Depth (cm)	Altitude to MSL (m)	Comments
66	4.837	a (1 slide)
68	4.817	a (1 slide)

DIATOM

Depth (cm)	Altitude to MSL (m)	Comments
66	4.837	s (2 slides-Nil)
68	4.817	s (2 slides-Nil)

69.5	4.802	a (2 slides)	69.5	4.802	s (2 slides-Nil)
71	4.787	a (1 slide)	71	4.787	s (2 slides-Nil)
73	4.767	a (1 slide)	73	4.767	s (2 slides-Very rare)
76	4.737	a (1 slide)	76	4.737	s (2 slides-Few)

Core no.: **KEC8**
Location: Mardi, Klang
Geographical co-ord.: 2°59'08"N, 101°29'48"E
Ground altitude: 6.435 m

POLLEN			DIATOM		
Depth (cm)	Altitude to MSL (m)	Comments	Depth (cm)	Altitude to MSL (m)	Comments
169	4.745	a (2 slides)	169	4.745	s (2 slides-Nil)
171	4.725	a (4 slides)	171	4.725	s (2 slides-Nil)
173	4.705	a (3 slides)	173	4.705	s (2 slides-Nil)
174.5	4.69	a (1 slide)	-	-	-
176	4.675	a (2 slides)	176	4.675	s (2 slides-Nil)
177	4.665	a (1 slide)	177	4.665	s (2 slides-Rare)
180	4.635	a (1 slide)	180	4.635	s (2 slides-Nil)

Core no.: **KEC9**
Location: Mardi, Klang
Geographical co-ord.: 2°59'08"N, 101°29'42"E
Ground altitude: 6.846 m

POLLEN			DIATOM		
Depth (cm)	Altitude to MSL (m)	Comments	Depth (cm)	Altitude to MSL (m)	Comments
183	5.016	a (2 slides)	-	-	-
185	4.996	a (2 slides)	185	4.996	s (2 slides-Nil)
187	4.976	a (2 slides)	187	4.976	s (2 slides-Nil)
190	4.946	a (1 slide)	190	4.946	s (1 slides-Nil)
192	4.926	a (1 slide)	192	4.926	s (2 slides-Nil)
195	4.896	a (1 slide)	195	4.896	s (2 slides-Nil)

Core no.: **KEC13**
Location: Mardi, Klang
Geographical co-ord.: 2°59'19"N, 101°30'33"E
Ground altitude: 5.698 m

POLLEN			DIATOM		
Depth (cm)	Altitude to MSL (m)	Comments	Depth (cm)	Altitude to MSL (m)	Comments
89	4.808	a (4 slides)	89	4.808	s (2 slides-Nil)
91	4.788	a (2 slides-Few)**	91	4.788	s (2 slides-Nil)
93	4.768	a (2 slides)	93	4.768	s (2 slides-Nil)
94.5	4.753	a (1 slide)	94.5	4.753	s (2 slides-Nil)
96	4.738	a (1 slide)	96	4.738	s (2 slides-Rare)
98	4.718	a (3 slides)	98	4.718	s (2 slides-Rare)
100	4.698	a (3 slides)	100	4.698	s (2 slides-Rare)
			105	4.648	p

** (Counted only 39 pollen grains from the 2 slides analysed)

FORAMINIFERA

Depth (cm)	Altitude to MSL (m)	Comments
97-98	4.728-4.718	s (present)
102-103	4.678-4.668	s (present)
106-107	4.638-4.628	s (present)
115-116	4.548-4.538	p

(Volume of sediment used in foraminifera preparation = ~5ml)

Core no.: **KUC15**
Location: Penor (north), Kuantan
Geographical co-ord.: 3°43'22"N, 103°16'27"E
Ground altitude: 3.514 m

POLLEN

Depth (cm)	Altitude to MSL (m)	Comments
39	3.124	p
42	3.094	a (1/2 slide)
44	3.074	a (1/8 slide)
47	3.044	a (1/2 slide)
49	3.024	p
51	3.004	a (1/4 slide)
55	2.964	a (1/2 slide)
58	2.934	p
60	2.914	a (1/2 slide)
62	2.898	p
70	2.814	a (1/4 slide)
80	2.714	a (1/4 slide)
90	2.614	a (1/2 slide)
98	2.534	a (1/4 slide)
105	2.464	a (1 slide)

DIATOM

Depth (cm)	Altitude to MSL (m)	Comments
39	3.124	p
42	3.094	s (Small to mod. amount)
44	3.074	s (Small to mod. amount)
47	3.044	s (2 slides-Nil)
51	3.004	s (2 slides-Nil)
55	2.964	s (2 slides-Nil)
60	2.914	s (2 slides-Nil)
70	2.814	s (2 slides-Rare)
80	2.714	s (2 slides-Nil)
90	2.614	s (2 slides-Nil)
98	2.534	p
105	2.464	p

Core no.: **KUC12**
Location: Penor (south), Kuantan
Geographical co-ord.: 3°40'30"N, 103°17'35"E
Ground altitude: 5.685 m

POLLEN

Depth (cm)	Altitude to MSL (m)	Comments
98	4.705	a (1/4 slide)
130	4.385	a (1 slide)
160	4.085	a (1/2 slide)
165	4.035	a (1 slide)

DIATOM

Depth (cm)	Altitude to MSL (m)	Comments
53	5.155	s (Rare to few)
55	5.135	s (Few to mod. amount)
60	5.085	s (Few to mod. amount)
67	5.015	s (Rare to few)
140	4.285	s (2 slides-Nil)
147	4.215	s (2 slides-Nil)
160	4.085	s (2 slides-Nil)

181	3.875	a (1/2 slide)	176	3.925	s (2 slides-Nil)
190	3.785	a (1 slide)			

Appendix 3

Laboratory preparation method

3.1 Pollen preparation (after Faegri and Iversen, 1975; Moore and Web, 1978)

1. Measure 0.5 cc of sediment by displacement in water using a 5 cc measuring cylinder.
2. Add 10% KOH and heat in boiling water for 30 minutes.
3. Decant through 180μm sieve, centrifuge and wash until liquid is unstained.
4. Add HF (not necessary for peat samples), heat in boiling water until sediment dispenses for about 1 hour. Stir, centrifuge and decant.
5. Add 10%HCl, heat in boiling water for 3-5 minutes. Centrifuge, decant and wash with distilled water, repeat. Transfer to small tubes.
6. Add glacial acetic acid, stir, centrifuge and decant.
7. Add acetylation mixture (1:9 conc. H_2SO_4/acetic anhydride) and stir well. Heat in boiling water bath for 1 minute, top up with glacial acetic acid, centrifuge and decant.
8. Add glacial acetic acid, stir, centrifuge and decant.
9. Add distilled water, stir and centrifuge. Repeat 2 times.
10. Wash with ethanol 2x to remove water. Centrifuge and decant.
11. Add 2 ml tertiary butyl alcohol, 2 drops of safranin and transfer into small sample vials. Centrifuge and decant.
12. Add silicone oil and leave for 12 hours.
13. Stir, label and made into slides. Store residue carefully.

3.2 Diatom preparation (after Palmer and Abbott, 1986)

1. Place 0.5 cc of sediment sample in a beaker (150 ml) and add about 60 ml of 30%H_2O_2.
2. Heat gently for 6 hours, adding distilled water as necessary. Check for strong effervescence.
3. Place coverslip onto warm hotplate, carefully stir sample, wait for about 2 seconds (this allows the sand to settle), and sample with polythene pipette.
4. Add about 2 drops to the middle of the cover slip and then add distilled water until the cover slip is covered. Allow to evaporate.
5. When dry place the cover slip (sample side down) onto a slide which has a few drops of Naphrax spread on it.

6. Place slide plus cover slip onto a hot hotplate for 3 seconds only, take off and then press gently with forceps on the cover slip to squeeze out any air. Allow to cool.
7. Label slide and store remaining diatom solution carefully (in case need to prepare extra slides).

3.3 Foraminifera preparation (after Scott and Medioli, 1980)

1. Place 5 cc sediment sample in beaker (150 ml). Half-filled with distilled water. Add 3-5 cc Calgon solution. Leave overnight. Stir lightly.
2. Wet sieve through 500 μm and 63 μm sieves (the 500 μm retains the coarse organics and allows the foraminifera to pass through to the 63 μm screen).
3. Sample caught in the 63 μm fraction is transferred in a beaker and distilled water is added, the sample is now ready for analysis. The 500 μm sieve is examined before being discarded.
4. Swirl sample and suck using polythene pipette from centre of the beaker. Spread sample/water mixture on analysing tray.
5. Scan/Identify/Pick the foraminifera using binocular microscope (with light source) and brush.

Appendix 4

Palynomorph and diatom classification

4.1 The palynomorphs main ecological division

Species	Reference	Ecology
Avicennia sp.	Linn.	Mangrove
Bruguiera spp.	Lamarck	
Rhizophora spp.	Linn.	
Sonneratia alba	J.J.Smith	
Sonneratia caseolaris	(L.) Engl.	
Thespesia sp.	Sol. ex Correa	
Rhizophoraceae		
Sonneratiaceae		
Acritarch		
Dinoflagellate cysts		
Foraminifera inner tests		
Tasmanitids type		
Casuarina equisetifolia	J.R.&G.Forster	Sandy coasts
Schefflera sp.	J.R.&G.Forster	
Terminalia sp.	Linn.	
Xylocarpus sp.	Koenig	
Brownlowia sp.	Roxb.	Back mangrove
Nypa fruticans	Wurmb	
Oncosperma tigillarium	(Jack) Ridley	
Phoenix sp.	Linn.	
Acrostichum aureum	Linn.	
Chomotriletes sp.		
Calophyllum sp.	Linn.	Coastal freshwater swamp
Campnosperma sp.	Thwaites	
Combretocarpus rotundatus	(Miq.) Danser	
Cyperaceae		
Durio carinatus	Mast.	
Garcinia spp.	Linn.	
Ilex sp.	Linn.	
Kostermansia sp.	Soegang	
Lophopetalum multinervuum	Ridley	
Neesia sp.	Blume	
Pometia sp.	Forster	
Freycinetia sp.		Swamp and lowland
Gymnacranthera eugeniifolia type	(A.DC.) Sinclair	
Lophopetalum floribundum	Wight	
Mallotus sp.	Lour.	
Nephelium spp.	Linn.	
Pandanus spp.	Parkins	
Stemonurus sp.	Blume	
Clerodendrum sp.	Linn.	Lowland open
Ficus spp.	Linn.	
Glochidion sp.	J.R.&G.Forster	
Macaranga sp.	Thou.	
Phyllanthus sp.	Linn.	

Trewia sp.	Linn.	
Trema sp.	Lour.	
Amaranthaceae/Compositae		
Gramineae		
Ulmaceae (undiff.)		

Adina sp.	Salisb.	Inland
Baccaurea sumatrana	M.A.	
Borasus tp.	Linn.	
Capparis sp.	Tourn. ex L.	
Chisocheton sp.	Blume	
Elaeocarpus type	Linn.	
Fagraea fragrans	Roxb.	
Iodes sp.	Blume	
Irvingia sp.	Hk.f.	
Korthalsia rigida	Blume	
?Korthalsia sp.	Blume	
Kunstleria sp.	Prain	
Myrica sp.	Linn.	
Phytocrene sp.	Wall.	
Pinanga sp.	Blume	
Salacca sp.	Reinw.	
Scolopia sp.	Schreb.	
Shorea sp.		
?Swietenia sp.	Jacquin	
Xerospermum sp.		
Melastomataceae (undiff.)		
Meliaceae (undiff.)		
Alstonia sp.	Roxb. Br.	
Barringtonia sp.	J.R.&G.Forster	
Dillenia sp.	Linn.	
Durio tp.	Adans.	
Iguanura tp.	Blume	
Licuala sp.	Wurmb.	
Madhuca sp.	Gmelin	
?Melia/Dysoxylum		
Mesua spp.	Linn.	
Myristica sp.	Boehmer	
?Annonaceae (undiff.)		
Euphorbiaceae (undiff.)		
Magnoliaceae		
Caesalpinia sp.	Linn.	
Daemonorops sp.	Bl. ex Schult.f.	
Eugenia type	Linn.	
Aglaia sp.	Lour.	
Aidia sp.	Lour.	
Altingia sp.	Norona	
Anacalosa sp.	Blume	
Aphanamixis sp.	Blume	
Apodytes sp.	E.Meyer ex Arn.	
Ardisia type	Swartz	
Arenga type	Labill.	
Calamus sp.	Linn.	
Casearia sp.	Jacquin	
Castanopsis/Lithocarpus type		

Clerodendron villosum	Blume
Daemonorops verticillaris type	(Griff.) Mart.
Eugeissona sp.	Griff.
Euonymus cochinchinensis type	Pierre
Fagraea auriculata	Jack
Flacourtia rukam	Zoll.&Mor.
Homalium sp.	Jacquin
Hydnocarpus sp.	Gaertn.
Melochia sp.	Dill.ex L.
Microtropis sp.	Wall. Ex Meisn.
Quercus sp.	Linn.
Randia sp.	Linn.
Rhopaloblaste sp.	Scheff.
Saraca sp.	Linn.
Sterculia sp.	Linn.
Symplocos type	Jacquin
Compositae (undiff.)	
Dipterocarpaceae (undiff.)	
Menispermaceae (undiff.)	
Moraceae/Urticaceae type	
Myrsinaceae	
Anacardiaceae (undiff.)	
Burseraceae (undiff.)	
Leguminosae (undiff.)	
Meliaceae/Sapotaceae	
Palmae (undiff.)	
Rubiaceae (undiff)	
Sapindaceae (undif.)	
Sapotaceae	
Pinus sp.	Linn.
Podocarpus imbricatus	Blume
Podocarpus sp.	L'Herit. ex Pers.
Dendropthoe pentandra	
Dianella type	
Annonaceae/Liliaceae/Palmae type	
Chenopodiaceae	
Convolvulaceae	
Malpighiaceae (undiff.)	
Unidentifieds (include the):	
-Broken/Torn	
-Broken/Corroded	
-Corroded/Degraded	
-Folded/Broken	
-Folded/Crumpled	
-Folded/Corroded	
-Folded/Hidden	
-Hidden/Obscured	

4.2 Palynomorphs not ecologically differentiated

Species	Reference	Palynomorph
Selaginella sp.	Spring	Fern spore
Asplenium sp.	Linn.	
Blechnum tp.	Linn.	
Cyathea sp.	Sm.	
Davallia type	Sm.	
Diplazium sp.	Sw.	
Lygodium microphyllum	(Cav.) R.Br.	
Nephrolepis type	Schott	
Pityrogramma calomelanos	(Linn.) Link	
Stenochlaena palustris	(Burm.f.) Bedd.	
?Stenochlaena sp.	J.Sm.	
Monolete (psilate)		
Monolete (undiff.)		
Trilete (undiff.)		
Vase-like		Fungal spore
Bulb-like		
Circular		
Undifferetiated		

4.3 Ecology of the diatom species

Species	Reference	Salinity	Life form
Eunotia monodon	Ehrenberg	halophobous	epiphytic
Frustulia rhomboids	(Ehren.) De Toni		epipelic
Pinnularia subcapitata	Greg.		aerophilous
Cymbella? sp.	Agardh	oligohalobous indifferent	epiphytic
Eunotia tenella	(Grun.) Hust.		epiphytic
Gomphonema parvulum	(Kutz.) Grun.		epiphytic
Gyrosigma scalproides	(Rabh.) Cl.		epipelic
Navicula avonensis	Round		epipelic
Navicula minima	Grun.		epipelic
Navicula rhynchocephala	Kutzing		epipelic
Navicula sp.	Bory		epipelic
Nitzschia parvula	Lewis		epipelic
Nitzschia pusilla	Hilse		epipelic
Pinnularia gentilis	(Donk.) Cl.		aerophilous
Pinnularia microstauron	(Ehren.) Cl.		aerophilous
Pinnularia obscura	Krasske		aerophilous
Stauroneis kriegeri	Patrick		epipelic
Cocconeis pediculus	Ehren.	oligohalobous halophile	epiphytic
Melosira italica	(Ehren.) Kutzing		planktonic
Navicula cryptocephala	Kutz.		epipelic
Navicula mutica	Kutz.		epipelic
Navicula tripunctata var *schizonemoides*	Patrick		epipelic
Nitzschia frustulum	(Kutz.) Grun.		epipelic
Rhopalodia gibberula			epiphytic
Achnanthes brevipes	Agardh	mesohalobous	epiphytic
Achnanthes delicatula	(Kutz.) Grun.		episammic
Amphora coffeaeformis	(Ag.) Kutz.		tychoplanktonic
Cyclotella striata	(Kutz.) Grun.		planktonic
Delphineis surirella	(Ehren.) Andrews		epiphytic
Diploneis bombus	(Ehren.) Kutzing		epipelic
Diploneis interrupta	(Kutz.) Cl.		aerophilous
Frustulia linkei	(Grun.) Cleve		epipelic
Gyrosigma balticum	(Ehren.) Cl.		epipelic
Navicula halophila	(Grun.) Cl.		epipelic
Nitzschia navicularis	(Breb.) Grun.		epipelic
Nitzschia punctata	(W.Sm.) Grun.		epipelic
Nitzschia sigma	W.Sm.		epipelic
Synedra fasciculata	(Ag.) Kutz.		epiphytic
Actinoptychus senarius	(Ehren.) Ehren.	polyhalobous	planktonic
Amphora dubia	Greg.		epipelic
Coscinodiscus blandus	(Breb.) Cleve		planktonic
Coscinodiscus obscurus	Grunow		planktonic
Coscinodiscus radiatus	Ehren.		planktonic

Coscinodiscus subtilis	Ehren.	planktonic
Diploneis smithii	(Breb.) Cl.	planktonic
Navicula flanatica	(Ehren.) Cleve	epipelic
Navicula lyra	Ehren.	epipelic
Navicula scoliopleura	A.Schmidt	epipelic
Nitzschia granulata	Grun.	epipelic
Nitzschia panduriformis	Greg.	epipelic
Odontella biddulphiana	J.E. Smith (Boyer)	planktonic
Opephora pacifica	(Grun.) Petit	episammic
Paralia sulcata	(Ehren.) Cl.	planktonic
Plagiogramma vanheurckii	Grunow	tychoplanktonic
Podosira stelliger	(Bail.) Mann	planktonic
Surirella fastuosa	Ehren.	epipelic
Thalassionema nitzschioides	Grun.	planktonic
Thalassiosira eccentrica	(Ehren.) Cl.	planktonic
Triceratum alternans	Bail.	planktonic
Triceratium favus	Ehren.	planktonic
Trybilioptychus cocconeiformis	(Cl.) Hendey	planktonic

Appendix 5

Pollen and diatom results

5.1 Pollen analysis of Kelang contemporary samples

Specie\Sample No.	KES 18	KES 21	KES 17	KES 19	KES 16	KES 20	KES 13	KES 11	KES 9	KES 7	KES 3
Avicennia sp.	1	0	0	0	2	0	0	0	1	4	0
Bruguiera spp.	3	0	3	3	6	0	4	8	9	15	6
Rhizophora spp.	26	5	30	0	38	3	48	42	62	76	73
Sonneratia alba	0	1	1	0	1	1	2	1	0	1	1
Sonneratia caseolaris	1	0	2	0	1	0	1	4	5	5	0
Rhizophoraceae	8	8	11	3	17	3	14	1	14	24	14
Casuarina equisetifolia	3	0	0	0	9	0	0	35	2	0	1
Schefflera sp.	0	0	0	0	0	0	2	0	0	0	0
Brownlowia sp.	0	0	0	1	0	0	0	0	0	0	0
Nypa fruticans	0	7	0	33	0	13	0	0	0	0	1
Oncosperma tigillarium	6	106	45	268	14	117	9	10	13	11	15
Phoenix sp.	0	0	0	0	0	0	1	0	0	0	0
Calophyllum sp.	0	0	0	0	1	0	1	0	2	0	0
Campnosperma spp.	0	2	18	9	3	1	4	3	6	5	5
Combretocarpus rotundatus	2	0	5	22	9	1	8	4	5	6	5
Cyperaceae	3	44	7	10	2	14	7	9	5	0	1
Garcinia spp.	1	0	1	0	2	0	0	0	0	0	0
Ilex sp.	2	10	6	28	2	6	0	3	3	3	5
Neesia sp.	0	0	0	0	0	0	0	0	1	0	0
Freycinetia sp.	1	0	0	0	0	0	1	0	0	2	0
Gymnacranthera eugeniifolia type	0	0	0	0	0	0	2	0	0	0	0
Lophopetalum floribundum	0	0	0	0	0	0	0	0	0	0	1
Mallotus sp.	0	0	0	0	0	0	0	0	0	2	0
Nephelium spp.	0	0	0	0	4	0	1	0	0	4	5
Pandanus spp.	1	4	3	0	8	2	6	4	9	9	5
Stemonurus spp.	0	0	0	1	0	0	0	0	2	1	0
Ficus spp.	0	2	2	0	18	0	8	5	10	5	4
Macaranga spp.	0	1	0	0	1	0	1	1	1	1	1
Phyllanthus sp.	0	0	0	1	0	0	1	0	0	0	0
Trewia sp.	0	0	0	0	0	0	0	0	0	0	2
Gramineae	44	17	4	8	7	10	7	6	3	8	5
Adina sp.	0	0	0	0	0	0	0	2	0	0	2
Caesalpinia sp.	7	0	0	0	0	0	0	0	0	0	0
Capparis sp.	0	0	0	0	0	0	0	0	3	0	0
Elaeocarpus spp.	19	6	18	27	22	2	11	11	14	16	11
Fagraea fragrans	0	0	0	0	0	0	1	0	0	0	0
Korthalsia rigida	0	0	0	0	1	0	0	0	0	0	0

Myrica sp.	18	0	0	0	5	0	1	19	1	1	0
Pinanga sp.	0	0	0	2	0	0	0	2	0	0	0
Salacca sp.	0	0	0	0	0	0	0	0	2	0	0
Shorea sp.	0	0	0	1	3	0	4	0	1	0	1
Melastomataceae (undiff.)	0	0	0	0	4	0	1	0	1	2	2
Meliaceae (undiff.)	3	1	3	3	0	2	0	1	7	3	2
Dillenia sp.	1	0	0	0	0	0	0	0	1	0	0
Iguanura type	0	0	0	0	1	0	1	0	0	0	0
Melia/Dysoxylum type	0	0	0	0	0	0	0	1	0	0	0
?Annonaceae (undiff.)	0	3	0	7	0	3	0	0	0	0	4
Euphorbiaceae (undiff.)	3	0	0	0	1	0	0	0	0	5	0
Magnoliaceae	12	0	0	0	0	0	0	0	0	0	0
Eugenia spp.	2	0	1	1	8	0	6	5	5	2	6
Aglaia sp.	0	0	0	0	2	0	1	0	3	2	1
Ardisia type	0	0	0	0	0	0	0	3	0	1	0
Arenga type	0	0	0	0	0	2	0	0	0	3	0
Calamus sp.	0	4	1	1	1	0	2	0	1	3	2
Casearia sp.	0	0	0	0	0	0	0	0	2	0	0
Castanopsis/Lithocarpus type	1	0	4	0	4	0	7	1	4	1	9
Daemonorops verticillaris type	0	0	0	0	0	0	2	0	0	0	0
Flacourtia rukam	0	0	0	0	0	1	0	0	0	0	0
Iodes sp.	0	0	0	0	1	0	0	3	0	0	0
Quercus sp.	0	0	0	1	4	0	3	2	4	2	7
Sterculia cordata type	0	0	0	0	0	0	0	0	1	0	0
Symplocos type	0	1	0	0	0	0	0	1	2	3	1
Compositae (undiff.)	1	6	2	16	0	1	0	1	1	0	1
Dipterocarpaceae (undiff.)	0	0	1	2	0	0	0	1	0	1	0
Menispermaceae (undiff.)	1	1	0	7	2	0	1	4	2	2	3
Moraceae/Urticaceae type	5	3	2	0	10	1	10	7	7	7	2
Anacardiaceae (undiff.)	0	1	0	1	0	0	0	0	0	0	1
Leguminosae (undiff.)	10	0	2	0	0	0	0	0	0	0	0
Palmae (undiff.)	0	6	3	5	2	1	1	1	2	0	2
Palmae/Liliaceae type	0	13	0	19	0	3	0	0	0	0	0
Rubiaceae (undiff.)	0	0	0	0	0	0	2	0	1	0	9
Sapindaceae	0	0	0	0	2	0	0	7	1	8	2
Pinus sp.	3	0	0	0	1	2	1	3	1	0	1
Podocarpus sp.	0	0	0	0	0	0	0	0	1	0	0
Ulmaceae (undiff.)	0	0	0	0	0	0	3	0	0	0	2
Convolvulaceae	0	0	0	0	0	0	0	0	3	0	0
Dianella type	16	17	1	8	7	10	3	0	9	0	3
Unidentified pollen	8	1	1	18	14	3	6	2	14	3	7
Broken/Torn	1	0	3	0	2	1	1	8	3	4	2

Broken/Corroded	0	2	0	7	0	2	1	2	0	1	0
Corroded/Degraded	1	11	4	20	3	7	1	3	5	5	4
Folded/Broken	0	0	0	0	0	0	0	0	2	3	2
Folded/Crumpled	0	2	3	3	11	10	2	2	8	13	5
Folded/Corroded	0	7	3	10	3	6	4	2	2	5	3
Folded/Hidden	0	0	1	0	0	0	0	0	1	2	0
Hidden/Obscured	1	5	3	0	2	3	0	1	3	2	4
Acrostichum aureum	3	18	12	26	10	29	8	16	16	18	10
Lycopodium cernuum (without perine)	0	0	0	0	4	1	2	59	1	1	0
Selaginella sp.	0	1	1	0	0	0	1	0	0	0	0
Asplenium sp.	0	20	0	60	11	49	12	10	11	19	13
Blechnum type	0	2	0	20	0	0	1	0	2	0	2
Crypsinus type	0	0	0	6	0	0	0	0	0	0	0
Cyathea sp.	0	0	1	0	4	0	9	7	4	1	3
Davallia type	0	3	0	1	1	3	0	4	0	4	2
Diplazium sp.	0	0	1	12	0	0	0	0	0	0	0
Lygodium microphyllum	0	0	0	16	0	4	0	0	0	0	0
Nephrolepis type	0	33	0	121	15	54	13	14	14	15	9
Pityrogramma calomelanos	0	0	0	0	0	0	0	0	0	2	0
Stenochlaena palustris	6	27	7	50	5	52	10	5	6	15	13
Monolete (psilate)	8	4	2	12	1	13	2	8	5	1	2
Monolete (undiff.)	19	9	7	47	0	26	4	3	8	4	10
Trilete (undiff.)	5	6	7	10	5	8	6	4	8	18	9
Dinoflagellate cysts	0	0	0	0	0	0	1	0	1	0	0
Foraminifera inner tests	0	0	1	0	1	0	6	1	4	3	0
?Tasmanitids	0	0	0	0	0	0	0	5	0	2	1
Fungal spores (undiff.)	89	408	34	530	109	828	52	40	81	112	84
Lycopodium (2 tab.)	2874	0	4246	149	878	314	1066	1696	1250	2277	1340
?Alnus sp. (contam.)	0	0	0	0	36	0	0	5	0	1	0
Coast	3	0	0	0	9	0	2	35	2	0	1
Mangrove	39	14	48	6	66	7	76	62	96	130	95
Back mangrove (incl. Acrostichum aureum)	9	131	57	328	24	159	18	26	29	29	26
Coastal freshwater swamp	8	56	37	69	19	22	20	19	22	14	16
Swamp and lowland	2	4	3	1	12	2	10	4	11	18	11
Lowland open	44	20	6	9	26	10	17	12	14	14	12
Inland	113	90	56	159	116	60	76	95	118	100	101
Fern spore (excl. A.aureum)	38	105	26	355	46	210	60	114	59	80	63
Fungal spore	89	408	34	530	109	828	52	40	81	112	84
Pollen sum (incl. A.aureum)	218	315	207	572	272	260	219	253	292	305	262
Pollen sum plus fern spores	256	420	233	927	318	470	279	367	351	385	325
Pollen sum plus fungal spores	307	723	241	1102	381	1088	271	293	373	417	346

5.2 Pollen analysis of Kuantan contemporary samples

Specie\Sample No.	KUPS15	KUPS14	KUPS13	KUS16	KUS17	KUS18	KUS15	KUS19	KUS20
Avicennia sp.	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Bruguiera spp.	10.0	2.0	0.0	1.0	0.0	0.0	8.0	1.0	0.0
Rhizophora spp.	3.0	0.0	58.0	48.0	13.0	93.0	67.0	79.0	80.0
Sonneratia alba	0.0	0.0	0.0	1.0	0.0	4.0	0.0	1.0	4.0
Sonneratia caseolaris	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
Rhizophoraceae	2.0	1.0	18.0	31.0	12.0	35.0	36.0	43.0	39.0
Sonneratiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Acritarch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dinoflagellate cysts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Foraminifera inner tests	1.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
?Tasmanitids	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Casuarina equisetifolia	14.0	8.0	4.0	1.0	0.0	0.0	1.0	0.0	3.0
Terminalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylocarpus	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brownlowia sp.	0.0	0.0	0.0	4.0	0.0	0.0	2.0	0.0	0.0
Nypa fruticans	0.0	1.0	1.0	1.0	0.0	1.0	0.0	6.0	1.0
Oncosperma tigillarium	22.0	24.0	57.0	4.0	3.0	4.0	6.0	6.0	6.0
Acrostichum aureum	12.0	7.0	14.0	22.0	10.0	3.0	8.0	28.0	14.0
Chomotriletes sp.	5.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Pediastrium sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Calophyllum sp.	5.0	1.0	19.0	2.0	0.0	2.0	2.0	43.0	6.0
Campnosperma spp.	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretocarpus rotundatus	3.0	0.0	36.0	23.0	5.0	18.0	17.0	54.0	50.0
Cyperaceae	52.0	29.0	23.0	264.0	286.0	28.0	9.0	6.0	3.0
Garcinia spp.	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ilex sp.	3.0	1.0	0.0	2.0	0.0	1.0	0.0	0.0	1.0
Neesia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pometia sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Freycinetia sp.	4.0	3.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Gymnacranthera eugeniifolia type	2.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Lophopetalum floribundum	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Nephelium spp.	1.0	1.0	7.0	0.0	0.0	3.0	6.0	2.0	1.0
Pandanus spp.	39.0	57.0	30.0	1.0	0.0	1.0	1.0	0.0	1.0
Stemonurus spp.	1.0	0.0	1.0	0.0	1.0	0.0	3.0	0.0	0.0
Ficus spp.	2.0	4.0	7.0	0.0	0.0	0.0	1.0	0.0	1.0

Macaranga spp.	1.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0
Phyllanthus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trewia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Gramineae (undiff.)	57.0	60.0	14.0	14.0	3.0	3.0	4.0	7.0	2.0
Adina sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capparis sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Elaeocarpus spp.	15.0	8.0	8.0	0.0	0.0	4.0	11.0	1.0	2.0
Myrica sp.	5.0	10.0	2.0	0.0	3.0	0.0	0.0	0.0	1.0
Phytocrene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salacca sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shorea sp.	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melastomataceae (undiff.)	8.0	1.0	3.0	0.0	0.0	1.0	0.0	1.0	1.0
Meliaceae (undiff.)	0.0	3.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Dillenia sp.	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
?Annonaceae (undiff.)	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbiaceae (undiff.)	0.0	1.0	1.0	2.0	0.0	0.0	0.0	1.0	2.0
Magnoliaceae	11.0	4.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Eugenia spp.	3.0	3.0	6.0	0.0	0.0	0.0	52.0	1.0	0.0
Aglaia sp.	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Aphanamixis sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apodytes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ardisia type	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenga type	1.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0
Calamus sp.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Casearia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Castanopsis/Lithocarpus type	1.0	0.0	4.0	1.0	0.0	2.0	6.0	1.0	0.0
Flacourtia rukam	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quercus sp.	1.0	3.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Compositae (undiff.)	1.0	1.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0
Dipterocarpaceae (undiff.)	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0
Menispermaceae (undiff.)	1.0	0.0	2.0	0.0	0.0	1.0	4.0	1.0	0.0
Moraceae/Urticaceae type	4.0	6.0	3.0	0.0	1.0	0.0	4.0	0.0	0.0
Anacardiaceae (undiff.)	0.0	0.0	1.0	0.0	0.0	1.0	2.0	0.0	0.0
Leguminosae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Palmae (undiff.)	2.0	2.0	2.0	0.0	0.0	2.0	0.0	1.0	0.0
Rubiaceae (undiff.)	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Sapindaceae	3.0	3.0	1.0	0.0	1.0	1.0	8.0	0.0	1.0
Pinus sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Podocarpus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dendropthoe pentandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0

Dianella type	0.0	3.0	2.0	0.0	0.0	2.0	2.0	0.0	0.0
Chenopodiaceae	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Convolvulaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Annonaceae/Liliaceae/Palmae type	1.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified pollen	20.0	6.0	5.0	4.0	0.0	0.0	8.0	4.0	2.0
Broken/Torn	5.0	4.0	2.0	1.0	0.0	1.0	3.0	2.0	2.0
Broken/Corroded	0.0	1.0	2.0	0.0	0.0	2.0	1.0	1.0	2.0
Corroded/Degraded	3.0	0.0	4.0	0.0	0.0	3.0	2.0	4.0	9.0
Folded/Broken	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Folded/Crumpled	13.0	19.0	10.0	5.0	0.0	9.0	3.0	7.0	6.0
Folded/Corroded	2.0	1.0	4.0	4.0	1.0	3.0	4.0	2.0	6.0
Folded/Hidden	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Hidden/Obscured	13.0	1.0	7.0	5.0	2.0	13.0	3.0	9.0	5.0
Lycopodium cernuum (without perine)	5.0	6.0	0.0	1.0	0.0	0.0	5.0	0.0	1.0
Selaginella sp.	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asplenium sp.	14.0	15.0	9.0	6.0	2.0	10.0	21.0	1.0	9.0
Blechnum type	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0
Cyathea sp.	2.0	5.0	7.0	0.0	0.0	0.0	4.0	0.0	0.0
Davallia type	4.0	9.0	2.0	0.0	0.0	0.0	0.0	1.0	1.0
Diplazium sp.	4.0	6.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
Lygodium microphyllum	7.0	14.0	1.0	0.0	0.0	0.0	0.0	2.0	5.0
Nephrolepis type	61.0	30.0	9.0	0.0	0.0	4.0	7.0	0.0	0.0
Pityrogramma calomelanos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stenochlaena palustris	37.0	39.0	15.0	2.0	1.0	0.0	4.0	1.0	1.0
?Stenochlaena sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monolete (psilate)	12.0	5.0	1.0	1.0	1.0	2.0	3.0	2.0	0.0
Monolete (undiff.)	28.0	13.0	7.0	5.0	3.0	3.0	16.0	11.0	5.0
Trilete (undiff.)	14.0	11.0	5.0	10.0	1.0	4.0	12.0	8.0	4.0
Fungal spores (undiff.)	87.0	204.0	23.0	109.0	89.0	22.0	83.0	97.0	98.0
Lycopodium (2 tab.)	444.0	364.0	470.0	194.0	227.0	891.0	3655.0	461.0	289.0
?Alnus sp. (contam.)	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0
Coast	16.0	8.0	4.0	1.0	0.0	0.0	1.0	0.0	3.0
Mangrove	16.0	3.0	77.0	81.0	25.0	133.0	121.0	125.0	127.0
Back mangrove (incl. A. aureum)	39.0	32.0	74.0	31.0	13.0	9.0	17.0	40.0	21.0
Coastal freshwater swamp	65.0	34.0	78.0	291.0	291.0	50.0	28.0	103.0	60.0
Swamp and lowland	47.0	62.0	38.0	1.0	1.0	4.0	14.0	2.0	2.0
Lowland open	60.0	67.0	23.0	14.0	3.0	3.0	5.0	7.0	5.0
Inland	138.0	89.0	77.0	27.0	11.0	51.0	120.0	41.0	41.0
Fern spore (excl. A.aureum)	188.0	154.0	56.0	25.0	8.0	23.0	76.0	26.0	27.0
Fungal spore	87.0	204.0	23.0	109.0	89.0	22.0	83.0	97.0	98.0

Pollen sum (incl. A.aureum)	381.0	295.0	371.0	446.0	344.0	250.0	306.0	318.0	259.0
Pollen sum plus fern spores	569.0	449.0	427.0	471.0	352.0	273.0	382.0	344.0	286.0
Pollen sum plus fungal spores	468.0	499.0	394.0	555.0	433.0	272.0	389.0	415.0	357.0

contd.....**5.2 Pollen analysis of Kuantan contemporary samples**

Specie\Sample No.	KUS13	KUS11	KUS9	KUS21	KUS7	KUS5	KUS3	KUS1
Avicennia sp.	5.0	3.0	0.0	0.0	0.0	3.0	2.0	0.0
Bruguiera spp.	5.0	5.0	3.0	0.0	4.0	0.0	19.0	2.0
Rhizophora spp.	80.0	92.0	64.0	90.0	138.0	147.0	64.0	81.0
Sonneratia alba	1.0	2.0	1.0	1.0	1.0	3.0	2.0	0.0
Sonneratia caseolaris	0.0	2.0	1.0	1.0	2.0	0.0	0.0	2.0
Rhizophoraceae	41.0	22.0	15.0	42.0	21.0	26.0	30.0	24.0
Sonneratiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acritarch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Dinoflagellate cysts	0.0	0.0	0.0	0.0	1.0	0.0	3.0	2.0
Foraminifera inner tests	1.0	0.0	6.0	2.0	5.0	0.0	3.0	6.0
?Tasmanitids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Casuarina equisetifolia	2.0	1.0	0.0	1.0	2.0	0.0	0.0	3.0
Terminalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Xylocarpus	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Brownlowia sp.	0.0	0.0	0.0	0.0	1.0	2.0	1.0	2.0
Nypa fruticans	1.0	0.0	0.0	4.0	0.0	1.0	0.0	0.0
Oncosperma tigillarium	3.0	6.0	4.0	8.0	15.0	3.0	6.0	5.0
Acrostichum aureum	3.0	1.0	2.0	3.0	4.0	4.0	4.0	4.0
Chomotriletes sp.	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Pediastrium sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calophyllum sp.	3.0	2.0	3.0	2.0	1.0	0.0	2.0	5.0
Campnosperma spp.	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0
Combretocarpus rotundatus	36.0	8.0	14.0	15.0	19.0	11.0	24.0	24.0
Cyperaceae	3.0	8.0	6.0	10.0	13.0	3.0	7.0	8.0
Garcinia spp.	0.0	1.0	0.0	5.0	1.0	1.0	0.0	1.0
Ilex sp.	1.0	1.0	0.0	2.0	0.0	0.0	1.0	2.0
Neesia sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Pometia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Freycinetia sp.	1.0	1.0	2.0	1.0	1.0	0.0	1.0	1.0
Gymnacranthera eugeniifolia type	0.0	2.0	2.0	0.0	1.0	0.0	0.0	0.0

Lophopetalum floribundum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nephelium spp.	4.0	3.0	6.0	0.0	2.0	0.0	0.0	1.0
Pandanus spp.	3.0	2.0	5.0	1.0	0.0	3.0	3.0	5.0
Stemonurus spp.	3.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0
Ficus spp.	0.0	2.0	1.0	0.0	0.0	1.0	3.0	2.0
Macaranga spp.	0.0	0.0	1.0	2.0	0.0	0.0	1.0	1.0
Phyllanthus sp.	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0
Trewia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gramineae (undiff.)	6.0	2.0	1.0	2.0	8.0	3.0	2.0	7.0
Adina sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Capparis sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Elaeocarpus spp.	7.0	9.0	9.0	2.0	11.0	0.0	10.0	9.0
Myrica sp.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Phytocrene	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Salacca sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Shorea sp.	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Melastomataceae (undiff.)	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0
Meliaceae (undiff.)	1.0	0.0	3.0	4.0	1.0	1.0	0.0	2.0
Dillenia sp.	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
?Annonaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnoliaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eugenia spp.	4.0	2.0	4.0	4.0	2.0	2.0	6.0	3.0
Aglaia sp.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Aphanamixis sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Apodytes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Ardisia type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenga type	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Calamus sp.	0.0	3.0	1.0	0.0	0.0	2.0	1.0	0.0
Casearia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Castanopsis/Lithocarpus type	3.0	3.0	3.0	1.0	1.0	2.0	1.0	0.0
Flacourtia rukam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Quercus sp.	2.0	0.0	1.0	0.0	5.0	3.0	1.0	2.0
Compositae (undiff.)	2.0	0.0	1.0	0.0	0.0	0.0	2.0	1.0
Dipterocarpaceae (undiff.)	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0
Menispermaceae (undiff.)	0.0	0.0	0.0	1.0	0.0	0.0	1.0	2.0
Moraceae/Urticaceae type	3.0	2.0	7.0	4.0	3.0	1.0	1.0	3.0
Anacardiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leguminosae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Palmae (undiff.)	2.0	0.0	1.0	3.0	2.0	0.0	1.0	0.0

Rubiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Sapindaceae	0.0	2.0	0.0	0.0	0.0	1.0	2.0	0.0
Pinus sp.	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0
Podocarpus sp.	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Dendropthoe pentandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dianella type	1.0	5.0	4.0	1.0	5.0	3.0	6.0	7.0
Chenopodiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Convolvulaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annonaceae/Liliaceae/Palmae type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified pollen	7.0	7.0	3.0	5.0	6.0	7.0	6.0	6.0
Broken/Torn	0.0	1.0	2.0	2.0	1.0	4.0	3.0	3.0
Broken/Corroded	1.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0
Corroded/Degraded	0.0	7.0	2.0	4.0	8.0	9.0	6.0	4.0
Folded/Broken	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Folded/Crumpled	4.0	1.0	6.0	2.0	6.0	5.0	8.0	3.0
Folded/Corroded	1.0	4.0	4.0	1.0	1.0	6.0	4.0	2.0
Folded/Hidden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hidden/Obscured	5.0	7.0	2.0	6.0	4.0	5.0	5.0	4.0
Lycopodium cernuum (without perine)	5.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0
Selaginella sp.	0.0	0.0	1.0	1.0	0.0	1.0	2.0	0.0
Asplenium sp.	13.0	7.0	8.0	12.0	12.0	18.0	11.0	28.0
Blechnum type	0.0	0.0	2.0	0.0	2.0	0.0	0.0	1.0
Cyathea sp.	3.0	8.0	4.0	0.0	11.0	0.0	8.0	13.0
Davallia type	2.0	0.0	3.0	2.0	3.0	0.0	1.0	2.0
Diplazium sp.	7.0	3.0	3.0	0.0	4.0	1.0	1.0	4.0
Lygodium microphyllum	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Nephrolepis type	9.0	9.0	6.0	0.0	3.0	1.0	6.0	9.0
Pityrogramma calomelanos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Stenochlaena palustris	8.0	3.0	4.0	1.0	10.0	5.0	7.0	7.0
?Stenochlaena sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monolete (psilate)	2.0	4.0	2.0	5.0	4.0	1.0	2.0	2.0
Monolete (undiff.)	1.0	3.0	7.0	7.0	9.0	7.0	4.0	11.0
Trilete (undiff.)	3.0	2.0	9.0	7.0	9.0	3.0	4.0	7.0
Fungal spores (undiff.)	39.0	29.0	25.0	72.0	70.0	60.0	57.0	69.0
Lycopodium (2 tab.)	1970.0	454.0	1366.0	807.0	1220.0	789.0	489.0	587.0
?Alnus sp. (contam.)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coast	2.0	1.0	0.0	1.0	2.0	0.0	2.0	3.0
Mangrove	133.0	126.0	90.0	136.0	172.0	179.0	123.0	118.0
Back mangrove (incl. Acrostichum aureum)	9.0	7.0	6.0	15.0	21.0	10.0	11.0	11.0
Coastal freshwater swamp	44.0	21.0	24.0	35.0	34.0	16.0	36.0	41.0

Swamp and lowland	11.0	8.0	15.0	2.0	4.0	3.0	5.0	10.0
Lowland open	6.0	4.0	4.0	4.0	10.0	4.0	6.0	10.0
Inland	45.0	57.0	57.0	42.0	59.0	56.0	69.0	60.0
Fern spore (excl. A.aureum)	53.0	39.0	51.0	36.0	68.0	37.0	46.0	85.0
Fungal spore	39.0	29.0	25.0	72.0	70.0	60.0	57.0	69.0
Pollen sum (incl. A.aureum)	250.0	224.0	196.0	235.0	302.0	268.0	252.0	253.0
Pollen sum plus fern spores	303.0	263.0	247.0	271.0	370.0	305.0	298.0	338.0
Pollen sum plus fungal spores	289.0	253.0	221.0	307.0	372.0	328.0	309.0	322.0

5.3 Pollen analysis of Kuantan contemporary samples (unidentified pollen types excluded from the inland assemblage)

Specie\Sample No.	KUPS15	KUPS14	KUPS13	KUS16	KUS17	KUS18	KUS15	KUS19	KUS20
Avicennia sp.	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
Bruguiera spp.	10.0	2.0	0.0	1.0	0.0	0.0	8.0	1.0	0.0
Rhizophora spp.	3.0	0.0	58.0	48.0	13.0	93.0	67.0	79.0	80.0
Sonneratia alba	0.0	0.0	0.0	1.0	0.0	4.0	0.0	1.0	4.0
Sonneratia caseolaris	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
Rhizophoraceae	2.0	1.0	18.0	31.0	12.0	35.0	36.0	43.0	39.0
Sonneratiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Acritarch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dinoflagellate cysts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Foraminifera inner tests	1.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
?Tasmanitids	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Casuarina equisetifolia	14.0	8.0	4.0	1.0	0.0	0.0	1.0	0.0	3.0
Terminalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylocarpus	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brownlowia sp.	0.0	0.0	0.0	4.0	0.0	0.0	2.0	0.0	0.0
Nypa fruticans	0.0	1.0	1.0	1.0	0.0	1.0	0.0	6.0	1.0
Oncosperma tigillarium	22.0	24.0	57.0	4.0	3.0	4.0	6.0	6.0	6.0
Acrostichum aureum	12.0	7.0	14.0	22.0	10.0	3.0	8.0	28.0	14.0
Chomotriletes sp.	5.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Pediastrium sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Calophyllum sp.	5.0	1.0	19.0	2.0	0.0	2.0	2.0	43.0	6.0
Campnosperma spp.	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretocarpus rotundatus	3.0	0.0	36.0	23.0	5.0	18.0	17.0	54.0	50.0
Cyperaceae	52.0	29.0	23.0	264.0	286.0	28.0	9.0	6.0	3.0
Garcinia spp.	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ilex sp.	3.0	1.0	0.0	2.0	0.0	1.0	0.0	0.0	1.0
Neesia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pometia sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Freycinetia sp.	4.0	3.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Gymnacranthera eugeniifolia type	2.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Lophopetalum floribundum	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Nephelium spp.	1.0	1.0	7.0	0.0	0.0	3.0	6.0	2.0	1.0
Pandanus spp.	39.0	57.0	30.0	1.0	0.0	1.0	1.0	0.0	1.0
Stemonurus spp.	1.0	0.0	1.0	0.0	1.0	0.0	3.0	0.0	0.0
Ficus spp.	2.0	4.0	7.0	0.0	0.0	0.0	1.0	0.0	1.0

Macaranga spp.	1.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0
Phyllanthus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trewia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Gramineae (undiff.)	57.0	60.0	14.0	14.0	3.0	3.0	4.0	7.0	2.0
Adina sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capparis sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Elaeocarpus spp.	15.0	8.0	8.0	0.0	0.0	4.0	11.0	1.0	2.0
Myrica sp.	5.0	10.0	2.0	0.0	3.0	0.0	0.0	0.0	1.0
Phytocrene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salacca sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shorea sp.	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Melastomataceae (undiff.)	8.0	1.0	3.0	0.0	0.0	1.0	0.0	1.0	1.0
Meliaceae (undiff.)	0.0	3.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Dillenia sp.	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
?Annonaceae (undiff.)	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbiaceae (undiff.)	0.0	1.0	1.0	2.0	0.0	0.0	0.0	1.0	2.0
Magnoliaceae	11.0	4.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Eugenia spp.	3.0	3.0	6.0	0.0	0.0	0.0	52.0	1.0	0.0
Aglaia sp.	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0
Aphanamixis sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apodytes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ardisia type	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenga type	1.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0
Calamus sp.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Casearia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Castanopsis/Lithocarpus type	1.0	0.0	4.0	1.0	0.0	2.0	6.0	1.0	0.0
Flacourtia rukam	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quercus sp.	1.0	3.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Compositae (undiff.)	1.0	1.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0
Dipterocarpaceae (undiff.)	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0
Menispermaceae (undiff.)	1.0	0.0	2.0	0.0	0.0	1.0	4.0	1.0	0.0
Moraceae/Urticaceae type	4.0	6.0	3.0	0.0	1.0	0.0	4.0	0.0	0.0
Anacardiaceae (undiff.)	0.0	0.0	1.0	0.0	0.0	1.0	2.0	0.0	0.0
Leguminosae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Palmae (undiff.)	2.0	2.0	2.0	0.0	0.0	2.0	0.0	1.0	0.0
Rubiaceae (undiff.)	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Sapindaceae	3.0	3.0	1.0	0.0	1.0	1.0	8.0	0.0	1.0
Pinus sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Podocarpus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dendropthoe pentandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0

Dianella type	0.0	3.0	2.0	0.0	0.0	2.0	2.0	0.0	0.0
Chenopodiaceae	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Convolvulaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Annonaceae/Liliaceae/Palmae type	1.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified pollen	20.0	6.0	5.0	4.0	0.0	0.0	8.0	4.0	2.0
Broken/Torn	5.0	4.0	2.0	1.0	0.0	1.0	3.0	2.0	2.0
Broken/Corroded	0.0	1.0	2.0	0.0	0.0	2.0	1.0	1.0	2.0
Corroded/Degraded	3.0	0.0	4.0	0.0	0.0	3.0	2.0	4.0	9.0
Folded/Broken	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
Folded/Crumpled	13.0	19.0	10.0	5.0	0.0	9.0	3.0	7.0	6.0
Folded/Corroded	2.0	1.0	4.0	4.0	1.0	3.0	4.0	2.0	6.0
Folded/Hidden	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Hidden/Obscured	13.0	1.0	7.0	5.0	2.0	13.0	3.0	9.0	5.0
Lycopodium cernuum (without perine)	5.0	6.0	0.0	1.0	0.0	0.0	5.0	0.0	1.0
Selaginella sp.	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asplenium sp.	14.0	15.0	9.0	6.0	2.0	10.0	21.0	1.0	9.0
Blechnum type	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0
Cyathea sp.	2.0	5.0	7.0	0.0	0.0	0.0	4.0	0.0	0.0
Davallia type	4.0	9.0	2.0	0.0	0.0	0.0	0.0	1.0	1.0
Diplazium sp.	4.0	6.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
Lygodium microphyllum	7.0	14.0	1.0	0.0	0.0	0.0	0.0	2.0	5.0
Nephrolepis type	61.0	30.0	9.0	0.0	0.0	4.0	7.0	0.0	0.0
Pityrogramma calomelanos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stenochlaena palustris	37.0	39.0	15.0	2.0	1.0	0.0	4.0	1.0	1.0
?Stenochlaena sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monolete (psilate)	12.0	5.0	1.0	1.0	1.0	2.0	3.0	2.0	0.0
Monolete (undiff.)	28.0	13.0	7.0	5.0	3.0	3.0	16.0	11.0	5.0
Trilete (undiff.)	14.0	11.0	5.0	10.0	1.0	4.0	12.0	8.0	4.0
Fungal spores (undiff.)	87.0	204.0	23.0	109.0	89.0	22.0	83.0	97.0	98.0
Lycopodium (2 tab.)	444.0	364.0	470.0	194.0	227.0	891.0	3655.0	461.0	289.0
?Alnus sp. (contam.)	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0
Coast	16.0	8.0	4.0	1.0	0.0	0.0	1.0	0.0	3.0
Mangrove	16.0	3.0	77.0	81.0	25.0	133.0	121.0	125.0	127.0
Back mangrove (incl. A. aureum)	39.0	32.0	74.0	31.0	13.0	9.0	17.0	40.0	21.0
Coastal freshwater swamp	65.0	34.0	78.0	291.0	291.0	50.0	28.0	103.0	60.0
Swamp and lowland	47.0	62.0	38.0	1.0	1.0	4.0	14.0	2.0	2.0
Lowland open	60.0	67.0	23.0	14.0	3.0	3.0	5.0	7.0	5.0
Inland	81.0	57.0	43.0	6.0	8.0	19.0	96.0	12.0	9.0
Unidentifieds	57.0	32.0	34.0	21.0	3.0	32.0	24.0	29.0	32.0
Fern spore (excl. A.aureum)	188.0	154.0	56.0	25.0	8.0	23.0	76.0	26.0	27.0

Fungal spore	87.0	204.0	23.0	109.0	89.0	22.0	83.0	97.0	98.0
Pollen sum (incl. A.aureum)	381.0	295.0	371.0	446.0	344.0	250.0	306.0	318.0	259.0
Pollen sum plus fern spores	569.0	449.0	427.0	471.0	352.0	273.0	382.0	344.0	286.0
Pollen sum plus fungal spores	468.0	499.0	394.0	555.0	433.0	272.0	389.0	415.0	357.0

contd…..**5.3 Pollen analysis of Kuantan contemporary samples (unidentified pollen types excluded from the inland assemblage)**

Specie\Sample No.	KUS13	KUS11	KUS9	KUS21	KUS7	KUS5	KUS3	KUS1
Avicennia sp.	5.0	3.0	0.0	0.0	0.0	3.0	2.0	0.0
Bruguiera spp.	5.0	5.0	3.0	0.0	4.0	0.0	19.0	2.0
Rhizophora spp.	80.0	92.0	64.0	90.0	138.0	147.0	64.0	81.0
Sonneratia alba	1.0	2.0	1.0	1.0	1.0	3.0	2.0	0.0
Sonneratia caseolaris	0.0	2.0	1.0	1.0	2.0	0.0	0.0	2.0
Rhizophoraceae	41.0	22.0	15.0	42.0	21.0	26.0	30.0	24.0
Sonneratiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acritarch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Dinoflagellate cysts	0.0	0.0	0.0	0.0	1.0	0.0	3.0	2.0
Foraminifera inner tests	1.0	0.0	6.0	2.0	5.0	0.0	3.0	6.0
?Tasmanitids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Casuarina equisetifolia	2.0	1.0	0.0	1.0	2.0	0.0	0.0	3.0
Terminalia sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Xylocarpus	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Brownlowia sp.	0.0	0.0	0.0	0.0	1.0	2.0	1.0	2.0
Nypa fruticans	1.0	0.0	0.0	4.0	0.0	1.0	0.0	0.0
Oncosperma tigillarium	3.0	6.0	4.0	8.0	15.0	3.0	6.0	5.0
Acrostichum aureum	3.0	1.0	2.0	3.0	4.0	4.0	4.0	4.0
Chomotriletes sp.	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Pediastrium sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calophyllum sp.	3.0	2.0	3.0	2.0	1.0	0.0	2.0	5.0
Campnosperma spp.	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0
Combretocarpus rotundatus	36.0	8.0	14.0	15.0	19.0	11.0	24.0	24.0
Cyperaceae	3.0	8.0	6.0	10.0	13.0	3.0	7.0	8.0
Garcinia spp.	0.0	1.0	0.0	5.0	1.0	1.0	0.0	1.0
Ilex sp.	1.0	1.0	0.0	2.0	0.0	0.0	1.0	2.0
Neesia sp.	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Pometia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Freycinetia sp.	1.0	1.0	2.0	1.0	1.0	0.0	1.0	1.0

Gymnacranthera eugeniifolia type	0.0	2.0	2.0	0.0	1.0	0.0	0.0	0.0
Lophopetalum floribundum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nephelium spp.	4.0	3.0	6.0	0.0	2.0	0.0	0.0	1.0
Pandanus spp.	3.0	2.0	5.0	1.0	0.0	3.0	3.0	5.0
Stemonurus spp.	3.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0
Ficus spp.	0.0	2.0	1.0	0.0	0.0	1.0	3.0	2.0
Macaranga spp.	0.0	0.0	1.0	2.0	0.0	0.0	1.0	1.0
Phyllanthus sp.	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0
Trewia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gramineae (undiff.)	6.0	2.0	1.0	2.0	8.0	3.0	2.0	7.0
Adina sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Capparis sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Elaeocarpus spp.	7.0	9.0	9.0	2.0	11.0	0.0	10.0	9.0
Myrica sp.	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
Phytocrene	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Salacca sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Shorea sp.	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Melastomataceae (undiff.)	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0
Meliaceae (undiff.)	1.0	0.0	3.0	4.0	1.0	1.0	0.0	2.0
Dillenia sp.	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
?Annonaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnoliaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eugenia spp.	4.0	2.0	4.0	4.0	2.0	2.0	6.0	3.0
Aglaia sp.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Aphanamixis sp.	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Apodytes sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Ardisia type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arenga type	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Calamus sp.	0.0	3.0	1.0	0.0	0.0	2.0	1.0	0.0
Casearia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Castanopsis/Lithocarpus type	3.0	3.0	3.0	1.0	1.0	2.0	1.0	0.0
Flacourtia rukam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Quercus sp.	2.0	0.0	1.0	0.0	5.0	3.0	1.0	2.0
Compositae (undiff.)	2.0	0.0	1.0	0.0	0.0	0.0	2.0	1.0
Dipterocarpaceae (undiff.)	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0
Menispermaceae (undiff.)	0.0	0.0	0.0	1.0	0.0	0.0	1.0	2.0
Moraceae/Urticaceae type	3.0	2.0	7.0	4.0	3.0	1.0	1.0	3.0
Anacardiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leguminosae (undiff.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Palmae (undiff.)	2.0	0.0	1.0	3.0	2.0	0.0	1.0	0.0
Rubiaceae (undiff.)	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Sapindaceae	0.0	2.0	0.0	0.0	0.0	1.0	2.0	0.0
Pinus sp.	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0
Podocarpus sp.	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Dendropthoe pentandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dianella type	1.0	5.0	4.0	1.0	5.0	3.0	6.0	7.0
Chenopodiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Convolvulaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annonaceae/Liliaceae/Palmae type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified pollen	7.0	7.0	3.0	5.0	6.0	7.0	6.0	6.0
Broken/Torn	0.0	1.0	2.0	2.0	1.0	4.0	3.0	3.0
Broken/Corroded	1.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0
Corroded/Degraded	0.0	7.0	2.0	4.0	8.0	9.0	6.0	4.0
Folded/Broken	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Folded/Crumpled	4.0	1.0	6.0	2.0	6.0	5.0	8.0	3.0
Folded/Corroded	1.0	4.0	4.0	1.0	1.0	6.0	4.0	2.0
Folded/Hidden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hidden/Obscured	5.0	7.0	2.0	6.0	4.0	5.0	5.0	4.0
Lycopodium cernuum (without perine)	5.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0
Selaginella sp.	0.0	0.0	1.0	1.0	0.0	1.0	2.0	0.0
Asplenium sp.	13.0	7.0	8.0	12.0	12.0	18.0	11.0	28.0
Blechnum type	0.0	0.0	2.0	0.0	2.0	0.0	0.0	1.0
Cyathea sp.	3.0	8.0	4.0	0.0	11.0	0.0	8.0	13.0
Davallia type	2.0	0.0	3.0	2.0	3.0	0.0	1.0	2.0
Diplazium sp.	7.0	3.0	3.0	0.0	4.0	1.0	1.0	4.0
Lygodium microphyllum	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Nephrolepis type	9.0	9.0	6.0	0.0	3.0	1.0	6.0	9.0
Pityrogramma calomelanos	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Stenochlaena palustris	8.0	3.0	4.0	1.0	10.0	5.0	7.0	7.0
?Stenochlaena sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monolete (psilate)	2.0	4.0	2.0	5.0	4.0	1.0	2.0	2.0
Monolete (undiff.)	1.0	3.0	7.0	7.0	9.0	7.0	4.0	11.0
Trilete (undiff.)	3.0	2.0	9.0	7.0	9.0	3.0	4.0	7.0
Fungal spores (undiff.)	39.0	29.0	25.0	72.0	70.0	60.0	57.0	69.0
Lycopodium (2 tab.)	1970.0	454.0	1366.0	807.0	1220.0	789.0	489.0	587.0
?Alnus sp. (contam.)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coast	2.0	1.0	0.0	1.0	2.0	0.0	2.0	3.0
Mangrove	133.0	126.0	90.0	136.0	172.0	179.0	123.0	118.0
Back mangrove (incl. Acrostichum aureum)	9.0	7.0	6.0	15.0	21.0	10.0	11.0	11.0

Coastal freshwater swamp	44.0	21.0	24.0	35.0	34.0	16.0	36.0	41.0
Swamp and lowland	11.0	8.0	15.0	2.0	4.0	3.0	5.0	10.0
Lowland open	6.0	4.0	4.0	4.0	10.0	4.0	6.0	10.0
Inland	27.0	30.0	36.0	22.0	33.0	20.0	36.0	37.0
Unidentifieds	18.0	27.0	21.0	20.0	26.0	36.0	33.0	23.0
Fern spore (excl. A.aureum)	53.0	39.0	51.0	36.0	68.0	37.0	46.0	85.0
Fungal spore	39.0	29.0	25.0	72.0	70.0	60.0	57.0	69.0
Pollen sum (incl. A.aureum)	250.0	224.0	196.0	235.0	302.0	268.0	252.0	253.0
Pollen sum plus fern spores	303.0	263.0	247.0	271.0	370.0	305.0	298.0	338.0
Pollen sum plus fungal spores	289.0	253.0	221.0	307.0	372.0	328.0	309.0	322.0

5.4 Diatom analysis of Kelang contemporary samples

Specie\Sample No.	KES3	KES7	KES9	KES11	KES13	KES15	KES16	KES17	KES18
Odontella biddulphiana	9.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coscinodiscus blandus	25.0	24.0	27.0	28.0	44.0	28.0	2.0	3.0	2.0
Coscinodiscus obscurus	20.0	15.0	14.0	10.0	7.0	4.0	0.0	0.0	0.0
Cyclotella striata	92.0	72.0	91.0	71.0	76.0	65.0	3.0	5.0	4.0
Paralia sulcata	2.0	3.0	0.0	2.0	4.0	0.0	0.0	0.0	0.0
Thalassionema nitzschioides	197.0	180.0	155.0	116.0	89.0	135.0	4.0	11.0	7.0
Thalassiosira eccentrica	26.0	14.0	19.0	12.0	6.0	2.0	0.0	3.0	0.0
Triceratum alternans	11.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trybilioptychus cocconeiformis	59.0	35.0	45.0	23.0	31.0	38.0	2.0	3.0	4.0
Amphora coffeaeformis	0.0	0.0	0.0	0.0	0.0	0.0	161.0	130.0	113.0
Navicula halophila	0.0	2.0	0.0	0.0	0.0	3.0	19.0	38.0	2.0
Nitzschia navicularis	0.0	1.0	1.0	0.0	5.0	1.0	0.0	0.0	0.0
Nitzschia sigma	2.0	13.0	3.0	10.0	6.0	4.0	0.0	0.0	1.0
Achnanthes brevipes	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cocconeis pediculus	0.0	0.0	1.0	0.0	0.0	0.0	9.0	10.0	2.0
Delphineis surirella	54.0	15.0	21.0	20.0	20.0	17.0	1.0	1.0	2.0
Eunotia monodon	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Eunotia tenella	0.0	0.0	1.0	1.0	3.0	1.0	2.0	1.0	0.0
Navicula tripunctata var. schizonemoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	1.0
Nitzschia frustulum	0.0	0.0	2.0	0.0	0.0	0.0	5.0	15.0	3.0
Diploneis bombus	3.0	2.0	2.0	3.0	0.0	0.0	0.0	0.0	0.0
Diploneis smithii	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosigma balticum	4.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0	1.0
Navicula flanatica	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicula scoliopleura	1.0	0.0	6.0	2.0	0.0	2.0	0.0	0.0	0.0
Achnanthes delicatula	0.0	0.0	5.0	0.0	0.0	0.0	258.0	281.0	326.0
Opephora pacifica	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
Polyhalobous	355.0	279.0	268.0	196.0	181.0	209.0	11.0	20.0	13.0
Mesohalobous	152.0	109.0	123.0	104.0	107.0	90.0	442.0	455.0	449.0
Oligohalobous halophile	0.0	0.0	3.0	0.0	0.0	0.0	14.0	32.0	6.0
Oligohalobous indifferent	0.0	0.0	1.0	1.0	3.0	1.0	2.0	1.0	0.0
Halophobous	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Plankton	441.0	348.0	351.0	262.0	257.0	272.0	11.0	25.0	17.0
Tychoplankton	2.0	16.0	4.0	10.0	11.0	8.0	180.0	168.0	116.0
Epiphytes	54.0	21.0	25.0	21.0	23.0	20.0	17.0	34.0	8.0
Epipelon	10.0	3.0	10.0	8.0	0.0	2.0	0.0	0.0	1.0
Episammon	0.0	0.0	5.0	0.0	0.0	0.0	261.0	281.0	326.0
Total diatom valves	507.0	388.0	395.0	301.0	291.0	302.0	469.0	508.0	468.0

5.5 Diatom analysis of Kuantan contemporary samples

	KUS1	KUS3	KUS5	KUS7	KUS21	KUS9	KUS11	KUS13	KUS20	KUS19	KUS15	KUS18
Actinoptychus senarius	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Coscinodiscus blandus	60.0	45.0	18.0	13.0	5.0	3.0	9.0	3.0	2.0	18.0	22.0	2.0
Coscinodiscus obscurus	13.0	6.0	8.0	3.0	2.0	2.0	2.0	1.0	3.0	6.0	8.0	8.0
Cyclotella striata	32.0	38.0	13.0	15.0	16.0	1.0	7.0	2.0	18.0	35.0	46.0	35.0
Paralia sulcata	8.0	8.0	20.0	8.0	3.0	0.0	3.0	4.0	0.0	8.0	15.0	6.0
Thalassionema nitzschioides	50.0	70.0	32.0	35.0	12.0	5.0	14.0	4.0	7.0	40.0	41.0	46.0
Thalassiosira eccentrica	32.0	26.0	5.0	17.0	3.0	2.0	7.0	4.0	1.0	8.0	13.0	4.0
Triceratum alternans	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphora coffeaeformis	13.0	8.0	77.0	68.0	80.0	91.0	75.0	143.0	80.0	71.0	6.0	1.0
Amphora dubia	7.0	1.0	5.0	3.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	1.0
Plagiogramma vanheurckii	6.0	3.0	3.0	2.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0
Achnanthes brevipes	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
Cocconeis pediculus	0.0	0.0	11.0	10.0	3.0	8.0	2.0	2.0	6.0	1.0	0.0	0.0
Cymbella ?	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Delphineis surirella	10.0	13.0	5.0	8.0	1.0	0.0	5.0	5.0	2.0	3.0	4.0	0.0
Eunotia monodon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunotia tenella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomphonema parvulum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopolodia gibberula	1.0	2.0	1.0	0.0	0.0	0.0	0.0	4.0	3.0	0.0	2.0	3.0
Synedra fasciculata	5.0	4.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diploneis bombus	2.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Diploneis smithii	3.0	4.0	5.0	3.0	1.0	0.0	1.0	0.0	10.0	21.0	3.0	3.0
Frustulia linkei	0.0	0.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Frustulia rhomboides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosigma balticum	3.0	4.0	0.0	5.0	1.0	0.0	2.0	0.0	0.0	3.0	2.0	0.0
Gyrosigma scalproides	0.0	0.0	0.0	0.0	0.0	0.0	14.0	6.0	1.0	1.0	0.0	0.0
Navicula avensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicula cryptocephala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicula flanatica	0.0	0.0	3.0	5.0	1.0	0.0	0.0	2.0	5.0	1.0	0.0	0.0
Navicula halophila	12.0	3.0	2.0	4.0	12.0	9.0	7.0	6.0	2.0	0.0	10.0	15.0
Navicula lyra	0.0	0.0	11.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Navicula minima	0.0	0.0	13.0	29.0	5.0	25.0	4.0	24.0	5.0	10.0	2.0	0.0
Navicula mutica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicula scoliopleura	21.0	20.0	4.0	11.0	2.0	0.0	3.0	4.0	1.0	8.0	1.0	0.0
Navicula tripunctata var. schizonemoides	0.0	0.0	0.0	0.0	6.0	5.0	6.0	12.0	22.0	24.0	38.0	9.0
Nitzschia frustulum	1.0	0.0	15.0	12.0	23.0	23.0	11.0	16.0	5.0	1.0	6.0	6.0
Nitzschia navicularis	0.0	0.0	0.0	0.0	4.0	0.0	11.0	4.0	3.0	6.0	5.0	20.0
Nitzschia panduriformis	17.0	11.0	0.0	8.0	54.0	2.0	0.0	0.0	0.0	0.0	0.0	5.0

Nitzschia punctata	3.0	3.0	0.0	2.0	0.0	13.0	28.0	12.0	6.0	10.0	8.0	7.0
Nitzschia pusilla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzschia sigma	3.0	2.0	0.0	1.0	0.0	0.0	3.0	1.0	1.0	4.0	5.0	2.0
Nitzschiz parvular	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauroneis kriegeri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnanthes delicatula	10.0	7.0	20.0	51.0	19.0	65.0	24.0	9.0	95.0	48.0	6.0	12.0
Opephora pacifica	4.0	6.0	1.0	2.0	0.0	0.0	1.0	1.0	0.0	0.0	2.0	0.0
Diploneis interrupta	0.0	2.0	6.0	6.0	0.0	3.0	2.0	1.0	2.0	3.0	3.0	9.0
Pinnularia microstauron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnularia obscura	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
Pinnularia subcapitata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polyhalobous	224.0	203.0	115.0	114.0	83.0	17.0	42.0	24.0	29.0	110.0	107.0	80.0
Mesohalobous	92.0	90.0	137.0	190.0	138.0	207.0	171.0	207.0	214.0	193.0	97.0	105.0
Oligohalobous halophile	2.0	2.0	27.0	22.0	32.0	36.0	19.0	34.0	36.0	26.0	46.0	18.0
Oligohalobous indifferent	0.0	0.0	0.0	0.0	1.0	0.0	14.0	6.0	1.0	2.0	0.0	60.0
Halophobous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plankton	196.0	195.0	96.0	91.0	41.0	13.0	42.0	18.0	31.0	115.0	145.0	104.0
Tychoplankton	26.0	12.0	85.0	73.0	80.0	94.0	77.0	144.0	80.0	71.0	6.0	2.0
Epiphytes	17.0	25.0	18.0	18.0	5.0	8.0	7.0	11.0	11.0	5.0	6.0	7.0
Epipelon	65.0	48.0	53.0	85.0	109.0	77.0	93.0	87.0	61.0	89.0	82.0	69.0
Episammon	14.0	13.0	21.0	53.0	19.0	65.0	25.0	10.0	95.0	48.0	8.0	12.0
Aerophilous	0.0	2.0	6.0	6.0	0.0	3.0	2.0	1.0	2.0	3.0	3.0	69.0
Total diatom valves	318.0	295.0	279.0	326.0	254.0	260.0	246.0	271.0	280.0	331.0	250.0	263.0

contd...**5.5 Diatom analysis of Kuantan contemporary samples**

	KUS17	KUS16	KUPS13	KUPS14	KUPS15
Actinoptychus senarius	0.0	0.0	0.0	0.0	0.0
Coscinodiscus blandus	0.0	1.0	0.0	0.0	0.0
Coscinodiscus obscurus	0.0	1.0	0.0	0.0	0.0
Cyclotella striata	1.0	4.0	0.0	0.0	0.0
Paralia sulcata	0.0	1.0	0.0	0.0	0.0
Thalassionema nitzschioides	0.0	1.0	2.0	0.0	0.0
Thalassiosira eccentrica	0.0	0.0	0.0	0.0	0.0
Triceratum alternans	0.0	0.0	0.0	0.0	0.0
Amphora coffeaeformis	0.0	0.0	0.0	0.0	0.0
Amphora dubia	0.0	0.0	0.0	0.0	0.0
Plagiogramma vanheurckii	0.0	0.0	0.0	0.0	0.0
Achnanthes brevipes	0.0	0.0	0.0	0.0	0.0

Cocconeis pediculus	0.0	0.0	0.0	0.0	0.0
Cymbella ?	0.0	0.0	4.0	5.0	2.0
Delphineis surirella	0.0	0.0	0.0	0.0	0.0
Eunotia monodon	0.0	0.0	14.0	41.0	23.0
Eunotia tenella	0.0	0.0	62.0	130.0	115.0
Gomphonema parvulum	0.0	0.0	8.0	13.0	30.0
Rhopolodia gibberula	0.0	0.0	0.0	0.0	0.0
Synedra fasciculata	0.0	0.0	0.0	0.0	0.0
Diploneis bombus	0.0	0.0	0.0	0.0	0.0
Diploneis smithii	0.0	0.0	0.0	0.0	0.0
Frustulia linkei	0.0	0.0	0.0	0.0	0.0
Frustulia rhomboides	0.0	0.0	92.0	85.0	81.0
Gyrosigma balticum	0.0	0.0	0.0	0.0	0.0
Gyrosigma scalproides	0.0	0.0	0.0	0.0	0.0
Navicula avensis	65.0	46.0	0.0	0.0	0.0
Navicula cryptocephala	0.0	0.0	26.0	23.0	9.0
Navicula flanatica	0.0	0.0	0.0	0.0	0.0
Navicula halophila	0.0	0.0	0.0	0.0	0.0
Navicula lyra	0.0	0.0	0.0	0.0	0.0
Navicula minima	0.0	0.0	0.0	0.0	0.0
Navicula mutica	0.0	0.0	9.0	4.0	0.0
Navicula scoliopleura	0.0	0.0	0.0	0.0	0.0
Navicula tripunctata var. schizonemoides	0.0	0.0	0.0	0.0	0.0
Nitzschia frustulum	0.0	0.0	0.0	0.0	0.0
Nitzschia navicularis	0.0	2.0	0.0	0.0	0.0
Nitzschia panduriformis	0.0	0.0	0.0	0.0	0.0
Nitzschia punctata	0.0	0.0	0.0	0.0	0.0
Nitzschia pusilla	62.0	5.0	1.0	2.0	0.0
Nitzschia sigma	0.0	0.0	0.0	0.0	0.0
Nitzschiz parvular	51.0	77.0	3.0	5.0	0.0
Stauroneis kriegeri	5.0	4.0	0.0	0.0	0.0
Achnanthes delicatula	0.0	0.0	0.0	0.0	0.0
Opephora pacifica	0.0	0.0	0.0	0.0	0.0
Diploneis interrupta	0.0	3.0	0.0	0.0	0.0
Pinnularia microstauron	0.0	0.0	11.0	4.0	18.0
Pinnularia obscura	91.0	101.0	5.0	20.0	10.0
Pinnularia subcapitata	0.0	0.0	33.0	49.0	31.0
Polyhalobous	0.0	4.0	2.0	0.0	0.0
Mesohalobous	1.0	9.0	0.0	0.0	0.0
Oligohalobous halophile	0.0	0.0	35.0	27.0	9.0
Oligohalobous indifferent	274.0	233.0	94.0	179.0	175.0
Halophobous	0.0	0.0	139.0	175.0	135.0

Plankton	1.0	8.0	2.0	0.0	0.0
Tychoplankton	0.0	0.0	0.0	0.0	0.0
Epiphytes	0.0	0.0	88.0	189.0	170.0
Epipelon	183.0	134.0	131.0	119.0	90.0
Episammon	0.0	0.0	0.0	0.0	0.0
Aerophilous	91.0	104.0	49.0	73.0	59.0
Total diatom valves	275.0	246.0	270.0	381.0	319.0

5.6 Pollen analysis of core KEC2, Meru, Kelang

Specie\Depth (cm)	66	68	70	71	73	76
Avicennia sp.	0	0	1	0	0	2
Bruguiera spp.	10	14	11	2	7	7
Rhizophora spp.	318	619	284	301	233	175
Sonneratia alba	0	0	0	0	0	2
Sonneratia caseolaris	2	1	0	5	1	2
Rhizophoraceae	37	21	44	11	16	20
Nypa fruticans	0	0	0	0	2	1
Oncosperma tigillarium	1	0	1	0	4	2
Calophyllum sp.	4	2	0	1	0	0
Campnosperma spp.	2	1	6	2	0	2
Combretocarpus rotundatus	6	0	2	0	0	0
Cyperaceae	12	14	9	12	3	6
Ilex sp.	0	0	0	0	0	1
Pometia sp.	4	0	3	0	0	0
Nephelium spp.	8	28	19	16	5	4
Pandanus spp.	0	1	0	0	1	3
Stemonurus spp.	0	0	2	0	0	0
Ficus spp.	2	1	1	0	2	0
Macaranga spp.	0	0	0	0	0	1
Mallotus sp.	0	0	2	0	0	0
Gramineae	2	0	0	1	0	1
Borasus type	0	0	0	4	0	0
Chisocheton sp.	0	1	0	0	0	0
Elaeocarpus spp.	40	8	14	9	1	3
Myrica sp.	0	0	0	0	1	0
Melastomataceae (undiff.)	3	0	1	0	0	0
Meliaceae (undiff.)	0	0	0	0	0	2
Durio type	0	0	0	0	1	0
Melia/Dysoxylum type	0	0	0	0	3	0
Eugenia spp.	0	0	0	1	2	2
Ardisia type	0	12	4	0	0	0
Casearia sp.	0	0	0	0	0	1
Castanopsis/Lithocarpus type	2	0	0	0	0	0
Clerodendron villosum	0	0	0	0	0	1
Euonymus cochinchinensis type	0	1	0	0	0	0
Symplocos type	0	1	0	0	0	0
Dipterocarpaceae (undiff.)	0	0	0	0	0	1
Rubiaceae (undiff.)	0	1	0	1	0	0
Pinus sp.	0	0	0	0	0	1
Malvaceae	0	0	3	0	0	0
Annonaceae/Liliaceae/Palmae type	0	0	0	1	0	0
Unidentified pollen	2	4	2	6	2	1
Broken/Torn	0	0	2	4	1	2
Broken/Corroded	0	4	0	0	3	1
Corroded/Degraded	20	16	11	4	13	5
Folded/Broken	0	2	0	1	0	0
Folded/Crumpled	15	17	9	6	3	8
Folded/Corroded	1	12	7	8	7	7
Folded/Hidden	2	0	0	0	0	0
Hidden/Obscured	2	9	7	7	3	1
Acrostichum aureum	814	474	383	285	152	34
Lycopodium cernuum (without perine)	1	0	1	1	0	1
Selaginella sp.	0	0	0	0	1	0
Asplenium sp.	231	71	78	36	1	2
Blechnum type	0	2	4	0	1	3
Cyathea sp.	0	0	0	0	0	1
Davallia type	0	1	10	5	0	0

Diplazium sp.	0	0	1	4	2	0
Lygodium microphyllum	1	1	3	0	0	0
Nephrolepis type	175	100	83	54	2	1
Stenochlaena palustris	33	18	70	21	9	1
Monolete (psilate)	0	29	5	25	5	6
Monolete (undiff.)	0	22	13	17	1	2
Trilete (undiff.)	3	7	1	2	2	1
Foraminifera inner tests	0	0	0	0	0	2
Fungal spore? (like-bulb)	0	0	0	1	0	0
Fungal spores (undiff.)	127	112	165	191	159	99
Lycopodium (2 tab.)	192	172	278	158	151	330
Mangrove	367	655	340	319	257	210
Back mangrove (incl. Acrostichum aureum)	815	474	384	285	158	37
Coastal freshwater swamp	28	17	20	15	3	9
Swamp and lowland	8	29	21	16	6	7
Lowland open	4	1	3	1	2	2
Inland	87	88	60	52	40	36
Fern spore (excl. A. aureum)	444	251	269	165	24	18
Fungal spore	127	112	165	192	159	99
Pollen sum (incl. A. aureum)	1309	1264	828	688	466	301
Pollen sum plus fern spores	1753	1515	1097	853	490	319
Pollen sum plus fungal spores	1436	1376	993	880	625	400

5.7 Pollen analysis of core KEC1, Meru, Kelang

Specie\Depth (cm)	105	107	109	111	113	116
Avicennia sp.	0	0	0	1	0	1
Bruguiera spp.	1	5	2	18	6	5
Rhizophora spp.	11	23	46	122	153	162
Sonneratia alba	0	0	0	1	0	1
Sonneratia caseolaris	0	0	0	2	0	0
Rhizophoraceae	3	9	4	26	35	23
Brownlowia sp.	2	0	0	0	0	0
Nypa fruticans	0	0	0	0	0	1
Oncosperma tigillarium	1	0	2	1	1	2
Calophyllum sp.	0	0	0	0	0	1
Campnosperma spp.	45	74	1	13	1	0
Combretocarpus rotundatus	0	2	0	1	0	1
Cyperaceae	1	7	4	3	1	4
Garcinia spp.	0	1	0	0	0	0
Ilex sp.	3	3	1	3	0	1
Freycinetia sp.	0	0	0	1	0	0
Nephelium spp.	3	4	9	11	4	4
Pandanus spp.	1	0	0	0	1	0
Stemonurus spp.	0	1	0	0	1	1
Ficus spp.	73	26	3	9	2	3
Gramineae	0	1	0	0	0	1
Chisocheton sp.	0	0	0	0	0	1
Elaeocarpus spp.	2	10	7	13	3	1
Melastomataceae (undiff.)	0	2	1	1	0	1
Meliaceae (undiff.)	0	0	0	2	1	1
Barringtonia sp.	0	0	0	0	1	0
Melia/Dysoxylum type	0	0	0	0	2	0
?Annonaceae (undiff.)	0	0	0	0	1	3
Eugenia spp.	63	53	3	10	3	1
Aglaia sp.	0	1	0	3	0	0
Ardisia type	0	0	0	0	0	1
Calamus sp.	0	0	0	1	0	0
Castanopsis/Lithocarpus type	2	0	0	0	0	1
Quercus sp.	1	0	0	1	1	1
Dipterocarpaceae (undiff.)	1	0	0	0	1	1
Menispermaceae (undiff.)	0	0	0	1	0	0
Anacardiaceae (undiff.)	0	0	0	1	0	0
Palmae (undiff.)	1	3	0	1	1	0
Sapindaceae	0	0	1	0	0	0
Podocarpus imbricatus	0	0	0	0	0	1
Unidentified pollen	2	1	1	6	6	4
Broken/Torn	2	1	1	2	1	3
Broken/Corroded	2	4	1	1	0	2
Corroded/Degraded	5	5	7	5	6	10
Folded/Broken	1	1	0	0	3	0
Folded/Crumpled	4	9	4	9	6	10
Folded/Corroded	6	1	0	1	6	14
Folded/Hidden	0	0	1	0	0	0
Hidden/Obscured	6	5	1	1	3	4
Acrostichum aureum	40	133	517	387	30	13
Lycopodium cernuum (without perine)	0	1	4	0	1	0
Asplenium sp.	71	253	102	202	1	4
Blechnum type	12	33	25	15	1	1
Cyathea sp.	0	0	0	0	5	1
Davallia type	1	7	7	3	0	1
Diplazium sp.	7	12	0	12	1	0
Lygodium microphyllum	0	0	1	0	1	0

Nephrolepis type	31	151	219	38	7	6
Stenochlaena palustris	93	92	99	69	8	7
?Stenochlaena sp.	0	2	0	0	0	0
Monolete (psilate)	264	118	159	6	14	7
Monolete (undiff.)	213	83	299	24	7	6
Trilete (undiff.)	2	2	6	3	1	1
Foraminifera inner tests	0	0	0	1	0	4
?Tasmanitids	0	0	0	0	1	2
Fungal spore? (like-vase)	0	2	0	10	0	0
Fungal spore? (like-bulb)	0	1	0	1	0	0
Fungal spores (undiff.)	205	234	64	56	68	48
Lycopodium (2 tab.)	364	1114	479	488	561	776
Mangrove	15	37	52	171	195	198
Back mangrove (incl. Acrostichum aureum)	43	133	519	388	31	16
Coastal freshwater swamp	49	87	6	20	2	7
Swamp and lowland	4	5	9	12	6	5
Lowland open	73	27	3	9	2	4
Inland	98	96	28	59	45	60
Fern spore (excl. A. aureum)	694	754	921	372	47	34
Fungal spore	205	237	64	67	68	48
Pollen sum (incl. A. aureum)	282	385	617	659	281	290
Pollen sum plus fern spores	976	1139	1538	1031	328	324
Pollen sum plus fungal spores	487	622	681	726	349	338

5.8 Pollen analysis of core KEC9, Mardi, Kelang

Specie\Depth (cm)	183	185	187	190	192	195
Bruguiera spp.	0	5	7	5	11	38
Rhizophora spp.	82	98	98	231	1218	301
Rhizophoraceae	17	11	20	25	58	87
Schefflera sp.	3	0	0	0	0	0
Oncosperma tigillarium	1	0	0	0	0	0
Phoenix paludosa	5	0	0	0	0	0
Calophyllum sp.	1	0	0	0	0	0
Campnosperma spp.	66	26	0	0	0	0
Combretocarpus rotundatus	1	0	0	0	0	0
Cyperaceae	1	1	0	0	4	2
Garcinia spp.	2	0	2	0	0	0
Ilex sp.	8	11	20	4	1	1
Freycinetia sp.	3	0	0	0	0	0
Lophopetalum floribundum	1	0	0	0	0	0
Nephelium spp.	16	17	38	42	50	1
Pandanus spp.	4	1	0	1	0	0
Stemonurus spp.	0	1	0	0	0	0
Ficus spp.	41	10	7	11	21	10
Macaranga spp.	0	0	3	0	0	0
Phyllanthus sp.	0	1	0	0	3	1
Gramineae	0	0	0	1	0	0
Adina sp.	0	0	1	0	0	0
Elaeocarpus spp.	8	8	4	10	11	2
Korthalsia rigida	0	0	0	1	0	0
Kunstleria sp.	0	0	2	0	0	0
Myrica sp.	25	8	2	0	0	0
Melastomataceae (undiff.)	0	0	0	0	2	0
Meliaceae (undiff.)	0	0	0	0	1	1
Iguanura type	5	0	0	0	0	0
?Annonaceae (undiff.)	0	0	3	5	2	0
Daemonorops sp.	0	0	1	0	3	0
Eugenia spp.	3	1	5	20	0	0
Altingia sp.	0	0	0	1	0	0
Calamus sp.	0	1	1	2	6	0
Castanopsis/Lithocarpus type	1	0	2	0	0	6
Daemonorops verticillaris type	9	7	1	0	0	0
Quercus sp.	0	0	2	1	4	0
Rhopaloblaste sp.	0	1	0	0	0	0
Dipterocarpaceae (undiff.)	9	0	0	0	0	3
Moraceae/Urticaceae type	0	0	0	0	2	1
Anacardiaceae (undiff.)	1	0	0	0	0	0
Caryophyllaceae (undiff.)	1	0	0	0	0	0
Palmae (undiff.)	0	2	2	1	5	0
Rubiaceae (undiff.)	0	0	4	2	2	0
Sapindaceae (undiff.)	5	1	0	0	0	0
Annonaceae/Liliaceae/Palmae type	0	0	1	0	6	0
Unidentified pollen	10	4	2	1	8	12
Broken/Torn	2	1	0	0	1	5
Broken/Corroded	0	1	0	1	0	0
Corroded/Degraded	8	4	2	3	16	4
Folded/Broken	0	0	0	0	1	0
Folded/Crumpled	3	8	8	26	36	24
Folded/Corroded	0	3	2	5	0	0
Hidden/Obscured	5	4	5	7	24	9
Acrostichum aureum	8	7	6	11	39	27
Lycopodium cernuum (without perine)	0	2	0	0	0	0
Asplenium sp.	6	5	0	0	0	0

Blechnum type	0	3	0	0	0	0
Cyathea sp.	0	0	0	0	4	0
Davallia type	0	2	6	2	4	2
Diplazium sp.	0	4	0	0	0	0
Nephrolepis type	6	8	11	14	66	6
Stenochlaena palustris	22	26	13	1	9	5
?Stenochlaena sp.	0	0	0	0	5	0
Monolete (psilate)	6	7	21	33	122	32
Monolete (undiff.)	5	9	0	0	4	0
Trilete (undiff.)	0	0	1	0	0	1
Chomotriletes sp.	0	2	6	0	0	0
Fungal spore? (like-vase)	50	66	123	8	10	8
Fungal spore? (like-bulb)	0	2	0	0	0	0
Fungal spore? (circ. & rad.)	0	0	1	1	0	0
Fungal spores (undiff.)	118	99	832	271	88	39
Lycopodium (2 tab.)	357	427	368	82	70	123
Coast	3	0	0	0	0	0
Mangrove	99	114	125	261	1287	426
Back mangrove (incl. Acrostichum aureum)	14	9	12	11	39	27
Swamp and lowland	24	19	38	43	50	1
Coastal freshwater swamp	79	38	22	4	5	3
Lowland open	41	11	10	12	24	11
Inland	95	54	50	86	130	67
Fern spore (excl. A. aureum)	45	66	52	50	214	46
Fungal spore	168	167	956	280	98	47
Pollen sum (incl. A. aureum)	355	245	257	417	1535	535
Pollen sum plus fern spores	400	311	309	467	1749	581
Pollen sum plus fungal spores	523	412	1213	697	1633	582

5.9 Pollen analysis of core KEC8, Mardi, Kelang

Specie\Depth (cm)	169	171	173	174	176	177	180
Bruguiera spp.	7	4	6	38	16	29	13
Rhizophora spp.	36	49	21	142	136	437	270
Sonneratia alba	0	0	1	0	0	1	0
Sonneratia caseolaris	0	0	0	0	1	0	0
Rhizophoraceae	28	22	11	50	15	58	24
Casuarina equisetifolia	0	0	1	0	0	0	0
Terminalia sp.	0	0	0	0	1	0	0
Nypa fruticans	0	0	1	0	0	0	2
Campnosperma spp.	12	14	17	7	2	1	0
Combretocarpus rotundatus	1	0	0	12	0	0	0
Cyperaceae	5	9	6	1	2	0	0
Garcinia spp.	0	0	1	0	1	0	1
Ilex sp.	23	15	11	10	4	1	0
Gymnacranthera eugeniifolia type	114	48	49	47	47	20	0
Nephelium spp.	17	11	7	40	27	13	0
Pandanus spp.	0	0	2	1	0	2	3
Stemonurus spp.	1	0	0	4	0	0	0
Ficus spp.	4	2	2	13	5	3	0
Phyllanthus sp.	3	3	0	2	0	0	0
Gramineae	0	0	1	0	0	0	1
Elaeocarpus spp.	21	31	0	22	4	0	0
Korthalsia rigida	0	0	0	0	0	1	0
?Korthalsia sp.	0	0	0	0	0	0	1
Myrica sp.	2	1	1	0	0	0	0
Shorea sp.	5	0	0	2	1	0	0
Meliaceae (undiff.)	0	1	1	0	1	0	0
Iguanura type	0	0	0	2	0	0	0
Melia/Dysoxylum type	0	0	0	0	1	0	1
Euphorbiaceae (undiff.)	0	1	0	0	5	2	0
Eugenia spp.	2	1	4	1	0	0	0
Homalanthus sp.	2	0	0	0	0	0	0
Aglaia sp.	1	1	2	0	0	0	0
Calamus sp.	10	9	3	8	52	1	0
Castanopsis/Lithocarpus type	0	0	0	2	0	0	0
Daemonorops verticillaris type	0	0	0	0	0	0	1
Saraca sp.	0	0	0	4	0	1	0
Moraceae/Urticaceae type	0	0	0	1	0	0	0
Anacardiaceae (undiff.)	0	0	0	1	0	0	0
Leguminosae (undiff.)	0	0	0	0	1	0	0
Palmae (undiff.)	1	0	7	0	1	0	0
Rubiaceae (undiff.)	0	1	0	0	2	1	0
Sapindaceae	0	3	0	0	0	0	0
Pinus sp.	1	0	0	0	0	0	0
Amaranthaceae/Compositae	0	0	1	0	0	0	0
Unidentified pollen	1	3	14	2	3	4	1
Broken/Torn	1	2	3	1	2	2	0
Corroded/Degraded	0	2	3	4	4	16	2
Folded/Broken	0	1	1	2	0	0	0
Folded/Crumpled	13	7	7	11	12	23	5
Folded/Corroded	6	8	1	8	4	14	3
Folded/Hidden	0	0	0	1	0	1	0
Hidden/Obscured	6	4	5	0	4	8	3
Acrostichum aureum	101	118	40	234	107	100	7
Selaginella sp.	0	1	0	0	0	0	0
Asplenium sp.	114	105	113	354	225	168	0
Blechnum type	9	6	0	23	1	0	0
Cyathea sp.	0	0	1	0	0	0	2

Davallia type	1	5	0	18	0	20	0
Diplazium sp.	7	21	0	45	0	0	0
Lygodium microphyllum	0	1	0	0	0	0	0
Nephrolepis type	160	158	85	389	194	228	3
Stenochlaena palustris	25	23	46	16	6	7	2
Monolete (psilate)	91	110	6	161	18	8	11
Monolete (undiff.)	21	42	0	71	0	0	0
Trilete (undiff.)	0	0	0	1	0	2	0
Chomotriletes sp.	0	1	0	0	0	0	0
?Tasmanitids	0	0	0	1	0	0	2
Fungal spore? (like-vase)	83	116	129	6	130	21	7
Fungal spore? (like-bulb)	17	33	72	15	30	19	0
Fungal spore? (circ. & rad.)	0	0	1	0	0	2	0
Fungal spores (undiff.)	132	118	830	70	518	189	74
Lycopodium (2 tab.)	404	1186	576	93	312	170	103
?Alnus sp. (contam.)	1	2	1	0	0	0	0
Coast	0	0	1	0	1	0	0
Mangrove	71	75	39	231	168	525	309
Back mangrove (incl. Acrostichum aureum)	101	119	41	234	107	100	9
Coastal freshwater swamp	41	38	35	30	9	2	1
Swamp and lowland	132	59	58	92	74	35	3
Lowland open	7	5	3	15	5	3	1
Inland	72	76	53	72	97	74	17
Fern spore (excl. A. aureum)	428	472	251	1078	444	433	18
Fungal spore	232	267	1032	91	678	231	81
Pollen sum (incl. A. aureum)	424	372	230	674	461	739	340
Pollen sum plus fern spores	852	844	481	1752	905	1172	358
Pollen sum plus fungal spores	656	639	1262	765	1139	970	421

5.10 Pollen analysis of core KEC7, Mardi, Kelang

Specie\Depth (cm)	66	68	70	71	73	76
Bruguiera spp.	2	11	23	73	67	98
Rhizophora spp.	17	72	105	275	184	251
Sonneratia alba	0	1	0	0	0	0
Rhizophoraceae	14	38	42	24	24	32
Schefflera sp.	2	7	5	0	3	1
Nypa fruticans	0	0	0	4	0	0
Oncosperma tigillarium	4	3	3	0	0	0
Campnosperma spp.	11	19	11	0	0	2
Combretocarpus rotundatus	0	0	2	0	0	0
Cyperaceae	2	7	0	3	0	2
Garcinia spp.	0	2	0	3	3	2
Ilex sp.	78	241	79	50	58	44
Lophopetalum multinervuum	0	0	0	0	2	1
Freycinetia sp.	0	0	2	0	0	0
Gymnacranthera eugeniifolia type	5	7	10	11	11	0
Nephelium spp.	8	12	26	51	9	18
Pandanus spp.	9	12	4	3	7	5
Stemonurus spp.	0	0	1	0	0	0
Ficus spp.	2	6	3	5	7	0
Phyllanthus sp.	1	0	0	0	0	1
Gramineae	1	1	3	1	2	2
Adina sp.	0	0	0	0	0	1
Baccaurea sumatrana	0	4	0	0	0	0
Capparis sp.	0	1	0	0	0	0
Elaeocarpus spp.	15	44	53	17	10	14
Myrica sp.	3	11	5	0	2	2
Shorea sp.	0	1	0	0	0	0
Xerospermum sp.	0	0	0	2	0	0
Melastomataceae (undiff.)	1	0	0	0	0	0
Meliaceae (undiff.)	0	2	0	0	0	0
Iguanura type	0	42	0	4	0	0
?Annonaceae (undiff.)	0	4	0	0	1	3
Euphorbiaceae (undiff.)	0	0	1	0	0	0
Eugenia spp.	11	43	4	4	0	2
Aglaia sp.	0	0	1	0	0	0
Ardisia type	0	6	0	23	15	14
Calamus sp.	0	1	0	1	0	0
Castanopsis/Lithocarpus type	0	1	1	0	0	1
Daemonorops verticillaris type	2	2	0	3	0	1
Flacourtia rukam	0	11	0	0	0	0
Quercus sp.	0	3	0	0	0	0
Rhopaloblaste sp.	11	0	0	0	2	0
Sterculia cordata type	0	0	2	0	0	0
Dipterocarpaceae (undiff.)	0	0	0	0	0	1
Moraceae/Urticaceae type	0	1	0	0	0	0
Anacardiaceae (undiff.)	0	1	0	10	0	0
Palmae (undiff.)	2	3	7	2	0	6
Rubiaceae (undiff.)	0	1	0	0	3	0
Tiliaceae (undiff.)	0	0	1	0	0	0
Podocarpus imbricatus	0	0	0	0	1	0
Amaranthaceae/Compositae	0	0	0	1	2	0
Annonaceae/Liliaceae/Palmae type	0	0	0	2	0	0
Unidentified pollen	1	16	4	6	18	5
Broken/Torn	0	1	2	4	2	1
Broken/Corroded	0	1	0	0	2	1
Corroded/Degraded	2	5	2	5	6	9
Folded/Broken	1	0	1	1	1	5

Folded/Crumpled	0	18	12	21	10	15
Folded/Corroded	3	2	13	10	4	2
Folded/Hidden	0	3	0	3	2	0
Hidden/Obscured	3	11	5	15	21	17
Acrostichum aureum	10	12	65	171	88	56
Lycopodium cernuum (without perine)	0	0	1	0	1	2
Selaginella sp.	0	0	1	0	0	0
Asplenium sp.	5	11	13	20	15	12
Blechnum type	0	8	1	5	0	0
Cyathea sp.	0	0	0	0	0	2
Davallia type	0	3	1	1	0	0
Diplazium sp.	2	0	3	0	0	0
Nephrolepis type	4	7	9	24	10	14
Stenochlaena palustris	89	270	81	78	34	42
Monolete (psilate)	2	8	3	5	10	5
Monolete (undiff.)	1	9	3	6	3	2
Trilete (undiff.)	1	1	1	6	1	2
?Tasmanitids	0	0	0	1	0	1
Fungal spore? (like-vase)	0	2	1	0	0	0
Fungal spore? (like-bulb)	1	0	7	0	1	0
Fungal spore? (circ. & rad.)	0	0	0	0	1	1
Fungal spores (undiff.)	127	759	131	457	395	336
Lycopodium (2 tab.)	138	141	288	172	127	104
Coast	2	7	5	0	3	1
Mangrove	33	122	170	373	275	382
Back mangrove (incl. Acrostichum aureum)	14	15	68	175	88	56
Coastal fresh water swamp	91	269	92	56	63	51
Swamp and lowland	22	31	43	65	27	23
Lowland open	4	7	6	6	9	3
Inland	55	239	114	134	102	100
Fern spore (excl. A. aureum)	104	317	117	145	74	81
Fungal spore	128	761	139	457	397	337
Pollen sum (incl. A. aureum)	221	690	498	809	567	616
Pollen sum plus fern spores	325	1007	615	954	641	697
Pollen sum plus fungal spores	349	1451	637	1266	964	953

5.11 Pollen analysis of core KEC13, Mardi, Kelang

Specie\Depth (cm)	89	93	94	96	98	100
Avicennia sp.	0	0	0	0	0	1
Bruguiera spp.	0	3	7	0	4	1
Rhizophora spp.	15	158	94	83	287	206
Sonneratia caseolaris	0	0	0	1	1	0
Rhizophoraceae	3	197	94	54	54	38
Schefflera sp.	0	0	0	0	2	0
Xylocarpus	0	0	0	0	1	0
Brownlowia sp.	2	0	0	0	0	0
Nypa fruticans	0	0	0	1	0	0
Calophyllum sp.	0	1	1	0	0	0
Campnosperma spp.	5	1	0	0	3	1
Cyperaceae	1	2	1	0	7	2
Garcinia spp.	0	1	0	1	0	1
Ilex sp.	0	0	1	0	2	0
Gymnacranthera eugeniifolia type	0	1	0	0	0	0
Nephelium spp.	4	2	5	2	3	1
Pandanus spp.	4	9	21	99	3	3
Ficus spp.	1	2	0	0	0	1
Elaeocarpus spp.	4	3	4	0	3	0
Myrica sp.	2	0	2	1	1	0
Shorea sp.	1	0	0	0	0	1
Melastomataceae (undiff.)	0	0	0	0	2	0
Meliaceae (undiff.)	1	0	0	1	3	0
Melia/Dysoxylum type	0	0	0	0	1	1
?Annonaceae (undiff.)	0	5	0	0	1	4
Daemonorops sp.	0	0	0	0	0	1
Eugenia spp.	1	0	0	0	1	1
Aglaia sp.	1	0	0	0	0	0
Ardisia type	0	4	0	0	1	2
Castanopsis/Lithocarpus type	0	0	2	0	2	0
Quercus sp.	0	1	0	0	0	0
Randia sp.	0	0	0	0	1	0
Dipterocarpaceae (undiff.)	0	0	0	0	2	1
Moraceae/Urticaceae type	0	0	0	0	1	0
Palmae (undiff.)	2	0	0	0	0	2
Sapindaceae	0	0	0	0	0	1
Podocarpus sp.	0	0	0	0	1	0
Malphigiaceae (undiff.)	0	0	0	0	0	1
Unidentified pollen	2	3	1	0	8	6
Broken/Torn	3	1	0	1	1	2
Broken/Corroded	0	0	0	0	2	3
Corroded/Degraded	0	2	1	1	4	13
Folded/Broken	1	0	0	0	0	0
Folded/Crumpled	1	5	4	2	6	7
Folded/Corroded	3	2	4	0	13	16
Folded/Hidden	0	2	0	1	0	0
Hidden/Obscured	6	8	3	5	5	9
Acrostichum aureum	72	53	34	13	7	6
Lycopodium cernuum (without perine)	0	0	1	0	0	1
Asplenium sp.	19	26	5	1	5	0
Blechnum type	15	7	2	0	0	3
Davallia type	7	3	1	0	1	0
Diplazium sp.	166	34	7	0	0	0
Lygodium microphyllum	5	0	0	0	0	0
Nephrolepis type	31	28	10	7	5	3
Stenochlaena palustris	26	9	1	3	3	3
Monolete (psilate)	2	10	0	0	0	0

Monolete (undiff.)	3	30	3	0	2	3
Trilete (undiff.)	0	0	0	0	0	2
Foraminifera inner tests	0	4	1	2	4	2
Chomotriletes sp.	1	1	0	0	0	0
Fungal spore? (like-bulb)	109	0	0	0	0	1
Fungal spores (undiff.)	118	133	125	33	138	155
Lycopodium (2 tab.)	665	271	103	72	408	276
Coast	0	0	0	0	3	0
Mangrove	18	362	196	140	350	248
Back mangrove (incl. Acrostichum aureum)	75	54	34	14	7	6
Coastal freshwater swamp	6	5	3	1	12	4
Swamp and lowland	8	12	26	101	6	4
Lowland open	1	2	0	0	0	1
Inland	28	36	21	12	59	71
Fern spore (excl. A. aureum)	274	147	30	11	16	15
Fungal spore	227	133	125	33	138	156
Pollen sum (incl. A. aureum)	136	471	280	268	437	334
Pollen sum plus fern spores	410	618	310	279	453	349
Pollen sum plus fungal spores	363	604	405	301	575	490

5.12 Pollen analysis of core KUC15, Penor (north), Kuantan

Specie\Depth (cm)	42	44	47	51	55	60	70	80	90	98	105
Bruguiera spp.	6	0	0	0	0	2	0	0	0	0	0
Rhizophora spp.	21	21	187	391	360	533	407	205	282	400	331
Sonneratia alba	0	0	0	0	0	0	0	1	0	0	0
Rhizophoraceae	27	19	184	168	52	84	54	15	39	37	29
Casuarina equisetifolia	0	1	0	0	0	0	0	0	0	1	0
Terminalia sp.	4	0	0	0	0	0	2	0	0	0	0
Oncosperma tigillarium	18	10	7	5	1	5	5	0	2	0	2
Phoenix sp.	0	0	0	1	0	0	0	0	0	0	0
Calophyllum sp.	20	11	3	2	1	1	0	0	1	0	1
Campnosperma spp.	5	2	2	0	0	0	1	0	0	0	1
Combretocarpus rotundatus	216	113	1544	116	21	73	66	11	13	37	16
Cyperaceae	12	4	0	2	1	0	2	0	1	0	1
Durio carinatus	14	4	0	0	0	0	0	0	0	0	0
Garcinia spp.	17	9	0	0	1	0	0	0	1	0	3
Ilex sp.	20	10	5	1	1	0	0	0	0	0	2
Lophopetalum multinervuum	0	1	0	0	0	0	0	0	0	0	0
Pometia sp.	20	13	0	0	0	1	0	0	0	0	0
Freycinetia sp.	35	23	0	0	0	0	2	0	0	0	0
Nephelium spp.	11	14	1	0	0	1	0	0	0	0	0
Pandanus spp.	52	23	5	0	0	1	1	0	0	0	1
Stemonurus spp.	4	3	2	1	0	1	0	0	1	0	0
Clerodendrum sp.	2	0	0	0	0	0	0	0	0	0	0
Ficus spp.	12	5	3	0	1	0	0	0	1	0	3
Macaranga spp.	14	7	0	2	0	0	2	1	0	0	0
Trema sp.	0	0	0	0	0	0	0	0	0	0	1
Gramineae	2	2	1	0	0	0	0	0	0	0	0
Ulmaceae (undiff.)	0	1	0	0	0	0	0	0	0	0	0
Capparis sp.	5	0	0	0	0	0	0	0	0	0	0
Elaeocarpus spp.	87	42	4	3	2	6	10	1	1	1	3
Myrica sp.	6	7	2	0	0	0	4	0	0	0	0
Pinanga sp.	0	1	1	0	0	0	0	0	0	0	0
Salacca sp.	5	2	4	0	0	0	0	0	0	0	0
Scolopia sp.	10	12	0	0	0	0	0	0	0	0	0
Melastomataceae (undiff.)	7	4	0	0	0	0	0	0	0	2	0
Meliaceae (undiff.)	49	15	9	2	1	2	1	0	0	1	0
Dillenia sp.	13	2	0	0	0	1	0	0	0	0	0
Melia/Dysoxylum type	17	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae (undiff.)	9	4	0	0	0	0	3	0	0	0	0

Eugenia spp.	10	7	0	2	2	1	2	1	0	3	0
Aglaia sp.	0	2	1	0	0	0	0	0	0	0	0
Aidia sp.	35	14	4	0	0	0	2	0	0	0	0
Ardisia type	2	14	0	4	0	0	3	0	0	0	0
Arenga type	0	0	0	2	0	0	2	0	0	0	0
Castanopsis/Lithocarpus type	1	2	0	0	0	0	0	0	0	3	2
Fagraea auriculata	1	0	0	0	0	0	0	0	0	0	0
Quercus sp.	5	1	0	0	0	0	0	0	0	0	0
Dipterocarpaceae (undiff.)	13	4	5	0	0	2	0	0	1	0	0
Menispermaceae (undiff.)	3	8	1	1	0	0	1	0	0	0	0
Moraceae/Urticaceae type	80	26	0	1	0	0	1	0	0	1	0
Myrsinaceae (undiff.)	6	0	0	0	0	0	0	0	0	0	0
Palmae (undiff.)	27	9	2	0	1	1	1	0	0	0	0
Rubiaceae (undiff.)	2	0	0	1	0	0	0	0	0	0	0
Sapindaceae	7	4	0	3	0	0	0	0	0	0	1
Unidentified pollen	25	25	1	3	3	1	5	0	1	2	1
Broken/Torn	7	3	0	3	2	0	3	0	2	3	0
Broken/Corroded	0	0	1	0	0	0	0	1	0	1	1
Corroded/Degraded	26	11	3	4	4	5	5	5	4	5	9
Folded/Broken	2	5	1	0	0	1	1	0	0	0	0
Folded/Crumpled	12	21	18	14	4	15	5	3	4	1	7
Folded/Corroded	7	3	0	4	5	1	5	6	7	6	6
Folded/Hidden	0	4	0	0	0	0	0	0	0	0	0
Hidden/Obscured	52	3	0	5	0	2	4	0	1	3	3
Acrostichum aureum	2	1	5	4	1	1	0	1	1	1	0
Lycopodium cernuum (without perine)	2	0	1	3	0	0	0	0	0	0	0
Asplenium sp.	0	0	0	6	1	0	1	1	2	1	4
Blechnum type	0	0	0	0	0	0	0	0	0	0	1
Cyathea sp.	34	6	0	0	0	0	0	0	0	0	0
Davallia type	2	5	6	0	2	0	0	0	1	1	1
Lygodium microphyllum	14	2	0	2	0	0	0	0	0	0	1
Nephrolepis type	0	0	0	1	2	0	0	0	0	1	0
Stenochlaena palustris	8	2	0	0	0	0	0	0	0	0	0
Monolete (psilate)	10	13	5	0	0	3	0	0	0	2	2
Monolete (undiff.)	20	8	6	2	0	0	3	0	0	1	1
Trilete (undiff.)	8	3	0	2	1	1	4	1	2	0	1
Foraminifera inner tests	0	0	0	0	0	0	0	0	0	0	2
Chomotriletes sp.	2	0	0	0	0	0	0	0	0	0	0
Fungal spores (undiff.)	40	5	3	6	11	17	5	10	10	7	31
Lycopodium (2 tab.)	82	27	80	45	87	98	78	26	36	59	91
Coast	4	1	0	0	0	0	2	0	0	1	0
Mangrove	54	40	371	559	412	619	461	221	321	437	362

Back mangrove (incl. Acrostichum aureum)	22	11	12	10	2	6	5	1	3	1	2
Coastal freshwater swamp	324	167	1554	121	25	75	69	11	16	37	24
Swamp and lowland	102	63	8	1	0	3	3	0	1	0	1
Lowland open	30	15	4	2	1	0	2	1	1	0	4
Inland	531	255	57	52	24	38	58	17	21	32	33
Fern spore (excl. A.aureum)	98	39	18	16	6	4	8	2	5	6	11
Fungal spore	40	5	3	6	11	17	5	10	10	7	31
Pollen sum (incl. A.aureum)	1067	552	2006	745	464	741	600	251	363	508	426
Pollen sum plus fern spores	1165	591	2024	761	470	745	608	253	368	514	437
Pollen sum plus fungal spores	1107	557	2009	751	475	758	605	261	373	515	457

5.13 Pollen analysis of core KUC12, Penor (south), Kuantan

Specie\Depth (cm)	98	130	160	165	181	190
Bruguiera spp.	0	0	2	11	2	0
Rhizophora spp.	3	6	7	34	3	3
Rhizophoraceae	5	5	2	7	2	0
Casuarina equisetifolia	0	0	0	4	0	0
Schefflera sp.	2	7	0	0	0	0
Brownlowia sp.	0	1	0	0	1	1
Oncosperma tigillarium	2	0	4	8	2	0
Calophyllum sp.	48	1	109	246	16	5
Campnosperma spp.	0	0	0	8	0	8
Combretocarpus rotundatus	7	0	2	13	1	0
Cyperaceae	1	5	0	2	6	4
Garcinia spp.	0	0	1	5	0	0
Ilex sp.	28	2	4	11	1	2
Kostermansia sp.	0	0	0	0	1	0
Neesia sp.	0	2	1	0	1	0
Pometia sp.	0	0	0	3	0	0
Freycinetia sp.	11	0	1	12	5	0
Gymnacranthera eugeniifolia type	1	0	0	0	0	3
Lophopetalum floribundum	0	0	0	0	1	2
Nephelium spp.	8	10	6	31	2	4
Pandanus spp.	31	119	9	67	14	19
Stemonurus spp.	8	1	2	4	3	4
Ficus spp.	5	3	1	11	5	10
Glochidion sp.	0	0	0	0	0	1
Macaranga spp.	1	6	0	4	0	11
Phyllanthus sp.	2	0	0	5	0	0
Gramineae	0	1	0	19	8	5
Ulmaceae (undiff.)	7	27	0	0	0	0
Baccaurea sumatrana	3	0	0	0	0	0
Capparis sp.	8	0	4	4	0	0
Elaeocarpus spp.	14	5	4	30	5	10
Fagraea fragrans	0	0	1	0	0	0
Irvingia sp.	0	1	0	0	0	0
Myrica sp.	1	0	5	9	0	8
Phytocrene sp.	1	0	0	0	0	0
Pinanga sp.	0	1	0	6	5	0
Melastomataceae (undiff.)	0	3	2	27	1	3
Meliaceae (undiff.)	5	7	29	66	97	83
Dillenia sp.	0	4	0	3	0	0
Durio type	0	0	3	0	1	0
Iguanura type	0	2	0	0	0	0
Licuala sp.	1	2	0	0	0	0
Madhuca sp.	0	1	0	0	0	0
Melia/Dysoxylum type	0	3	0	34	0	36
Mesua spp.	0	27	0	24	0	20
?Annonaceae (undiff.)	4	5	0	11	0	0
Euphorbiaceae (undiff.)	2	0	5	0	2	0
Magnoliaceae	2	0	3	0	0	0
Daemonorops sp.	0	1	0	2	0	0
Eugenia spp.	20	11	14	54	1	7
Aglaia sp.	0	1	0	7	0	0
Aidia sp.	1	0	16	49	9	0
Aphanamixis sp.	0	0	0	0	0	1
Apodytes sp.	0	0	0	0	0	5
Ardisia type	19	12	9	16	5	0
Arenga type	4	0	0	19	5	0
Calamus sp.	1	2	0	4	0	0
Casearia sp.	2	3	5	27	1	0
Castanopsis/Lithocarpus type	5	21	3	8	0	3

Daemonorops verticillaris type	0	0	0	0	0	1
Eugeissona sp.	0	0	0	3	0	0
Fagraea auriculata	0	1	0	0	0	0
Flacourtia rukam	0	0	0	11	0	0
Homalium sp.	0	0	0	7	0	0
Microtropis type	8	0	0	0	0	0
Quercus sp.	0	0	0	4	5	4
Randia sp.	0	0	0	0	1	0
Sterculia sp.	0	4	0	6	0	0
Compositae (undiff.)	1	0	0	0	0	1
Dipterocarpaceae (undiff.)	1	0	1	3	0	5
Menispermaceae (undiff.)	3	3	1	12	4	2
Meliaceae/Sapotaceae type	0	2	0	3	0	0
Moraceae/Urticaceae type	4	17	33	84	15	6
Anacardiaceae (undiff.)	0	2	0	0	0	2
Burseraceae (undiff.)	0	1	0	0	0	0
Leguminosae (undiff.)	0	0	0	0	0	1
Palmae (undiff.)	5	5	8	16	4	6
Rubiaceae (undiff.)	2	1	0	5	0	0
Sapindaceae	1	3	0	7	1	3
Pinus sp.	0	0	0	0	1	0
Podocarpus sp.	0	7	0	0	0	2
Dianella type	0	0	2	0	0	0
Annonaceae/Liliaceae/Palmae type	0	0	0	2	0	0
Unidentified pollen	18	23	7	28	14	72
Broken/Torn	8	8	5	18	6	10
Broken/Corroded	4	2	0	4	2	1
Corroded/Degraded	8	13	7	28	17	17
Folded/Broken	0	6	1	7	3	5
Folded/Crumpled	13	23	12	61	10	33
Folded/Corroded	11	15	11	23	12	14
Folded/Hidden	0	1	0	1	0	1
Hidden/Obscured	6	11	26	14	12	21
Acrostichum aureum	0	0	0	0	0	2
Lycopodium cernuum (without perine)	0	0	8	8	8	14
Asplenium sp.	4	1	3	0	7	0
Blechnum type	0	0	1	1	2	0
Davallia type	5	1	1	3	0	0
Diplazium sp.	1	0	3	0	0	0
Lygodium microphyllum	0	0	0	2	0	0
Pityrogramma calomelanos	0	0	2	0	0	0
Stenochlaena palustris	1	0	4	11	8	6
Monolete (psilate)	2	5	1	41	8	45
Monolete (undiff.)	2	1	8	5	6	8
Trilete (undiff.)	7	3	24	69	18	37
Fungal spore? (circ. & rad.)	0	0	0	2	0	0
Fungal spores (undiff.)	232	146	101	308	36	16
Lycopodium (2 tab.)	200	246	57	269	154	257
Coast	2	7	0	4	0	0
Mangrove	8	11	11	52	7	3
Back mangrove (incl. Acrostichum aureum)	2	1	4	8	3	3
Coastal freshwater swamp	84	10	117	288	26	19
Swamp and lowland	59	130	18	114	25	32
Lowland open	15	37	1	39	13	27
Inland	186	260	217	747	239	383
Fern spore (excl. A.aureum)	22	11	55	140	57	110
Fungal spore	232	146	101	310	36	16
Pollen sum (incl. A.aureum)	356	456	368	1252	313	467
Pollen sum plus fern spores	378	467	423	1392	370	577
Pollen sum plus fungal spores	588	602	469	1562	349	483

5.14 Diatom analysis of core KEC2, Meru, Kelang

Specie\Depth (cm)	68.0	70.0	71.0	73.0	76.0
Coscinodiscus radiatus	0.0	0.0	0.0	11.0	19.0
Coscinodiscus subtilis	0.0	0.0	0.0	22.0	76.0
Coscinodiscus sp.	0.0	0.0	0.0	0.0	30.0
Diploneis smithii	0.0	0.0	0.0	0.0	5.0
Nitzschia granulata	0.0	0.0	0.0	0.0	13.0
Paralia sulcata	0.0	5.0	25.0	90.0	169.0
Podosira stelliger	0.0	0.0	0.0	0.0	2.0
Surirella fastuosa	0.0	0.0	0.0	0.0	1.0
Thalassiosira eccentrica	0.0	0.0	0.0	0.0	49.0
Triceratium favus	0.0	0.0	0.0	28.0	37.0
Trybilioptychus cocconeiformis	0.0	0.0	1.0	4.0	29.0
Cyclotella striata	45.0	58.0	213.0	414.0	632.0
Diploneis bombus	0.0	6.0	3.0	2.0	14.0
Nitzschia navicularis	0.0	1.0	3.0	13.0	46.0
Synedra fasciculata	0.0	0.0	0.0	18.0	98.0
Melosira italica	0.0	0.0	6.0	12.0	14.0
Navicula rhynchocephala	0.0	0.0	0.0	5.0	6.0
Navicula sp.	0.0	0.0	0.0	5.0	6.0
Pinnularia gentilis	0.0	0.0	3.0	1.0	0.0
Polyhalobous	0.0	5.0	26.0	155.0	430.0
Mesohalobous	45.0	65.0	219.0	447.0	790.0
Oligohalobous-halophile	0.0	0.0	6.0	12.0	14.0
Oligohalobous-indifferent	0.0	0.0	3.0	11.0	12.0
Planktonic	45.0	63.0	245.0	581.0	1057.0
Epiphytic	0.0	0.0	0.0	18.0	98.0
Epipelic	0.0	7.0	6.0	25.0	91.0
Aerophilic	0.0	0.0	3.0	1.0	0.0
Total diatom	45.0	70.0	254.0	625.0	1246.0

5.15 Diatom analysis of core KEC1, Meru, Kelang

Specie\Depth (cm)	111.0	113.0	116.0
Coscinodiscus sp.	0.0	7.0	7.0
Paralia sulcata	0.0	9.0	3.0
Cyclotella striata	32.0	120.0	88.0
Diploneis bombus	9.0	8.0	3.0
Nitzschia navicularis	13.0	9.0	4.0
Polyhalobous	0.0	16.0	10.0
Mesohalobous	54.0	137.0	95.0
Planktonic	32.0	136.0	98.0
Epipelic	22.0	17.0	7.0
Total diatom	54.0	153.0	105.0